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JAMES EDWARD KEELER.

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

That "death loves a shining mark" is once more exemplified in the case of Professor Keeler. His life exhibited not only a long array of worthy accomplishments but a brilliant promise for the future. In the very prime of life and vigor of faculty, with all the benefits of a ripe experience, who will say what secrets he might not have wrested from the universe in the allotted span of human life?

What a loss to astronomy and the scientific world! To the Observatory over which he presided! But above all, what a cruel, crushing loss to a devoted family!

Professor Keeler was descended from New England stock on both sides. His first American ancestor was Ralph Keeler, who settled in Hartford, Conn., in 1635. His father was Wm. F. Keeler, Paymaster in the United States Navy, and an officer of the original "Monitor."

His mother, Anna E. Keeler, is still living. She is a daughter of Henry Dutton, former Judge of the Supreme Court, Governor of Connecticut and Dean of the Yale Law School.

James Edward Keeler was born in La Salle, Ill., September 10, 1857. He was one of four children, of whom only one sister survives. His early education was received in the public schools of his native town. In November 1869 the family removed to Mayport, Florida, where his studies were pursued at home.

He seems to have evinced early in life a decided mechanical turn, and a fondness for the natural sciences. It is not evident just what turned his attention to astronomy, but in all probability it was almost a natural selection to one of his nature and tastes. The first reference to astronomical matters in his diary is under date of September 22, 1875, as follows:—

"After supper went up in the lookout and took the altitude of the North Star, 31° 05′, liable to inaccuracy on account of indistinct vision through the sights of my quadrant."

About a month later he writes—"Concluded to get a two inch

achromatic and Huyghenian ocular for my telescope." Later these optical parts were ordered and his telescope constructed: the mounting being of the alt-azimuth form, complete with tripod and finder. The lenses were tested, and the powers of his eye-pieces were determined.

After the completion of his telescope, here is the very matter of fact way in which he describes what must have been to him an exciting moment—his first opportunity to test his instrument on the stars, after a long and trying cloudy period, during which he had to be content with observing terrestrial objects:

"Directed my telescope to the stars and saw the rings of Saturn for the first time. Could not see any satellites. Observed the gibbous phase of Venus with difficulty." The following nights were spent in observing a long list of objects.

He was not afraid of the discomforts incident to astronomical work, for we find him rising at 4:30 A. M. on January 26th following to observe Jupiter, and continuing until stopped by the sun.

His attention was apparently fastened, for in 1877 his astronomical equipment was increased by the addition of a meridian-circle. This instrument was of his own construction, the axis being neatly turned from cedar wood, into which the telescope was screwed. Spider threads were used, and illuminated in the usual way by means of a hollow axis and a diagonal reflector. The wooden circle was made up of sections, the graduations being on paper. With this instrument and an ordinary clock he determined the places of some of the brighter stars and planets, and the latitude of his observatory. He named his observatory the "Mayport Astronomical Observatory." His observing book contains many excellent sketches of lunar craters, the planets and double stars: where the components of the latter are colored, the colors have been reproduced.

His telescope and tripod complete as well as the axis and tube of his meridian circle, have been preserved.

A very pronounced feature in all his work was the painstaking care exercised in everything which he undertook, even to his notes, a characteristic which is strongly marked in his work as an amateur. His very first observations show the true scientific spirit which he possessed, recognizing what was important and recording it no matter how seemingly trivial, omitting the superfluous, and going straight to the core of a subject.

In the winter of 1877 he entered Johns Hopkins University,

graduating in 1881 with the degree of Bachelor of Arts. In 1882 he received the appointment as Graduate Scholar of the University for one year.

While a student he helped defray his expenses by assisting at the lectures and in the laboratory, and by making computations for some of the almanacs.

During his attendance at the University he made lasting friendships with some of the foremost men in science, and through them entered seriously into astronomical work.

While a student at Johns Hopkins University and not yet twenty-one years old he was selected as a member of the party sent out by the United States Naval Observatory to Central City, Col., in charge of Professor Holden, to observe the total solar eclipse of July 29, 1878. The report of his observations and his drawing of the corona are published in the U. S. Naval Observatory Report of that eclipse.

Immediately after his graduation he was engaged by Prof. Langley as assistant at the Allegheny observatory. He took part at once in the preparations which Professor Langley was making for the expedition to Mt. Whitney, Cal., to determine anew the value of the solar constant. The expedition left Allegheny on July 7, 1881, returning on September 28. The conditions for this work were found to be much better at Mt. Whitney than at any of the stations at which a previous determination had been made, and the resulting value of the constant is therefore reliable in proportion. The observations at Mt. Whitney showed that the absorption of heat by the earth's atmosphere was much greater than appeared from observations made at lower levels. A full account of this expedition and of the results obtained is published as No. XV of the *Professional Papers of the Signal Service.*

His work at Allegheny consisted largely in work with the Bolometer which Professor Langley was then perfecting and which was being used for the detection and measurement of heat radiations from the celestial bodies. He found time for the observation of other phenomena, notably the planets and the transit of Venus of December 5, 1882. He independently observed the bright spot which appeared on the exterior limb of Venus during this transit.

In 1883 Mr. Keeler went to Germany for a year to continue his studies, sailing from Baltimore on May 10, on the S. S. "Braunschweig." He arrived in Bremen on the 24th and from there

went to Heidelberg where he matriculated at the University on June 9. His principle work was in the Physical Laboratory under Professor Quincke whose lectures on the Undulatory Theory of Light he attended. He also attended lectures on Chemistry by Professor Bunsen and on Integral Calculus by Professor Fuchs.

In the Fall he spent a month's vacation traveling in Italy, visiting the principal cities and points of interest. Upon his return from Italy he went to Berlin, entered the University on October 16. Here as in Heidelberg, much of his work was in the laboratory. He attended lectures by von Helmholtz, Kayser, Runge and Glan. On June 4, 1884 he sailed from Bremen for New York, where he arrived on the 14th.

Returning to Allegheny in August he resumed his work at the observatory with Professor Langley, where he remained until 1886.

In the latter year he came to California as Assistant to the Lick Trustees, and took up his residence at the observatory, which was then nearing completion. Arriving at Mt. Hamilton on April 25th, he immediately began the installation of the time service. The observatory equipment was soon in order, but owing to delays in the construction of the telegraph line and in furnishing the necessary instruments, the regular transmission of signals to San Jose did not commence until January 1, 1887. Besides the work connected with the time service, he made observations with such other of the instruments as were then in readiness.

Upon the formal transfer of the Observatory to the Regents of the University in June 1888, Professor Keeler was appointed Astronomer.

His ingenuity devised many valuable devices and improvements about the observatory. One of these in the time-service consisted of a new break-circuit attachment for the Hohwü clocks and is in use yet. Upon the completion of the 36-inch refractor he devised a magnetic control for its driving clock, for use especially in photography where accurate following was necessary. By means of this attachment the driving clock was controlled by one of the standard clocks and almost perfect coincidence was obtained without any jarring.

The first spectroscope for the great equatorial was designed by him. At that time photography had not established itself in this department of astronomical research, and the instrument was therefore planned for visual observations only. With it all the

spectroscopic work up to 1894 was done, when new conditions and new requirements entered the problem.

The Lick Observatory undertook to establish a standard meridian line for Santa Clara county. This work was successfully accomplished by Professor Keeler in August 1889.

On January 1, 1889, a total eclipse of the Sun occurred which was visible in California. The belt of totality passed across the state about 150 miles north of Mt. Hamilton. An expedition was sent out from the Lick Observatory in charge of Professor Keeler. The eclipse station was established at Bartlett Springs in Lake county and a successful program carried through, Professor Keeler's portion consisting in repeating the spectroscopic observations made by Professor Hastings in 1883 in the Caroline Islands. The full report of this eclipse is published as No. 1 of the *Contributions from the Lick Observatory*.

In February of the same year Professor Keeler determined the position of the eclipse station at Norman, Colusa county, occupied by Professor Pritchett's party from Washington University.

Professor Keeler's work has been largely of a physical nature probably the result of early associations and training.

As soon as the 36-inch refractor was completed and before a suitable spectroscope could be provided much of his time was given to visual and micrometrical observation of the planets. Being a skilled artist he undertook the delineation of planetary details, securing excellent series of Mars, Jupiter and Saturn. Besides these many observations were made of the other planets and especially of the form of and the markings on the satellites of Jupiter.

He was in charge of the spectroscopic work, and as soon as possible began systematic researches in this line. In his observations of the spectra of the nebulae he early suspected that the discordances between the positions obtained for the chief nebular line in different nebulae could not be explained by supposing them to be due to instrumental causes, or to uncertainties in the observations. By a careful investigation he proved conclusively that these apparent discrepancies were due to motions of the nebulæ in the line of sight, and hence that the same conditions of motion that existed among the stars also existed among the nebulæ. Previous to this the observations of this character had not been of sufficient accuracy to disclose this fact.

On June 1, 1891 he resigned his post as Astronomer in the Lick

Observatory to accept the position of Professor of Astrophysics in the Western University of Pennsylvania and Director of the Allegheny Observatory, succeeding Professor Langley.

His services at the Lick Observatory were so highly prized as to call forth the following resolution from the Regents of the University:—

Resolved, that in accepting the resignation of Mr. Keeler, the Regents desire to express their high appreciation of his astronomical work at the Lick Observatory and that they wish him every success in his new position."

During his directorship at Allegheny his time was largely devoted to spectroscopic observations of the stars by means of photography, using a spectrograph of his own designing.

His adaptation of the spectroscope to the problem of determining the character of Saturn's Ring was most ingenious. Clerk Maxwell had shown a third of a century before, from mathematical considerations, that this appendage of the planet must consist of a multitude of small bodies, each revolving in its own orbit. The instrumental proof was lacking, however, until April 1895 when Professor Keeler with his new spectrograph attached to the 13-inch equatorial of the Allegheny Observatory, succeeded in obtaining photographs of the planet's spectrum of such excellence that the relative motions of different portions of the Ring were disclosed at once. The observed motions accorded perfectly with the theory. An accurate measurement and reduction of the displacements of the lines showed wonderful agreement with those computed from the known dimensions of the system.

In March 1898, Professor Keeler was elected Director of the Lick Observatory to fill the vacancy caused by the resignation of Professor Holden. He assumed the duties of his office on June 1.

Early in the present summer he contracted a heavy cold which obliged him to give up observing for a time and to place himself under the care of a physician. His condition was not considered at all serious, however. The last of July he went to San José for treatment, and then to Lake county with his family for a short vacation. Not feeling so well there, he returned to San Francisco, accompanied by Mrs. Keeler. On August 10th, while en route, he suffered a light stroke of appoplexy and on August 12th came the fatal stroke. He had apparently been subject to heart disease for many years.

Prof. Keeler was married at Oakley Plantation, Louisiana, June 16, 1891, to Miss Cora Slocomb Matthews, daughter of William Wilson and Isabel Matthews, and niece of the wife of

Captain R. S. Floyd, President of the Lick trustees. Mrs. Keeler and two children, Henry Bowman and Cora Floyd, survive him.

The crowning work of his life was undoubtedly his skillful administration of the Lick Observatory and his monumental work with the Crossley Reflector. Upon taking charge of the Lick Observatory, he made this instrument his especial care, determined to see what its possibilities were. He went about his task with that care and deliberateness which characterized all his investigations. After making a careful examination and trial of the instrument, its defects were one by one eliminated until the results were of the highest possible excellence.*

The first photograph was taken on September 15, 1898 and was for experimental purposes only. By November 4 the instrument was in condition and regular work was begun. The first object photographed was Brooks' Comet, of which a considerable series was secured. On November 16, 1898 a photograph of the Orion Nebula was secured which Professor Keeler pronounced "superb." During this time improvements were still being made: subsequently the changes and additions were slight, although continuing as long as the instrument was used.

He became very much attached to the Reflector and often spoke affectionately of it, believing thoroughly in its power as a photographic instrument. His first thought was that it would be most efficient in the spectroscopic field. The first trials were made, however, with the instrument as an ordinary photographic telescope, and during these its great efficiency in showing the structure of the nebulae determined him to explore this field more thoroughly. This work was in progress at the time of his death. The work already done in this direction has led to some very far-reaching conclusions, e. g., the immense number of faint nebulae yet undiscovered; and of more importance, the prevalence of the spiral structure among these bodies. Notwithstanding the magnitude of the work in hand he did not lose sight of the spectroscopic problems. The ease with which a photographic impression was secured of the central star in the Annular Nebula in Lyra suggested to him the possibility of photographing the spectra of such faint objects on a small scale. To this end he designed a slitless spectrograph to be used with the Crossley Reflector for this especial purpose. An instrument after these de-

* The June number of the *Astrophysical Journal* contains a very complete account of the work with the Crossley Reflector by Professor Keeler. This article will also be reprinted in the *Publications* of the Astronomical Society of the Pacific.

signs was constructed at the observatory but not completed in time for him to use. An early trial of it will be made.

Arrangements have been made to continue the work which Professor Keeler began with the Crossley Reflector, and the first efforts will be devoted to completing the program which he had under way — that of photographing all the brighter nebulae within reach of the telescope. In the prosecution of this work two new asteroids were found on the negatives by Professor Keeler. One at least of these was so faint that it could not be seen with certainty in the large refractor.

Professor Keeler was affiliated with many of the most prominent scientific societies. He was a member of the National Academy of Sciences; Fellow of the American Association for the Advancement of Science; Associate of the American Academy of Arts and Sciences; Fellow of the American Philosophical Society; Honorary Member of the Astronomical and Physical Society of Toronto; Fellow and Foreign Associate of the Royal Astronomical Society; Member and Councilor of the Astronomical and Astrophysical Society of America; Member and President of the Astronomical Society of the Pacific, and others. He was President of the Academy of Science and Art of Pittsburgh, 1897–98.

Professor Keeler was associate editor of *Astronomy and Astro-Physics* 1892–94 and editor (with Professor George E. Hale) of the *Astrophysical Journal* since its establishment in 1895.

As the "expert agent" required by the contract with Alvan Clark & Sons, Professor Keeler was invited by Professor Hale to test the objective for the 40-inch Yerkes telescope in 1895.

At the dedication of the Yerkes Observatory Professor Keeler delivered one of the addresses.

In 1893 the University of California conferred upon him the degree of Sc. D. in recognition of his scientific work.

In 1898 he was awarded the Rumford medals by the American Academy of Arts and Sciences "for his application of the spectroscope to astronomical problems, and especially for his investigations of the proper motions (line of sight motions) of the nebulae, and the physical constitution of the rings of the planet Saturn, by the use of that instrument." At the annual meeting of the National Academy of Sciences held in Washington, April 18-20, 1899, the Henry Draper gold medal was awarded to Professor Keeler.

Professor Keeler was a broad and liberal minded man, and made an ideal director. Tactful and judicious in dealing with

men he harmonized all interests and had the fullest confidence of everyone. He took the greatest interest in each man's work, giving encouragement, furnishing every assistance, and allowing the freest possible hand. In illustration of his modesty it is said of him that when discussing the work of the Observatory, he would speak enthusiastically of the successes of his associates without even referring to his own.

One of his greatest ambitions was to secure some time an endowment for the Lick Observatory, sufficient for all its needs.

Though quiet and studious in his tastes he was genial and kindly and had also many close friends outside of scientific circles. Especial mention should be made of Mr. William Thaw's kind interest and helpfulness in advancing Professor Keeler's career when he knew him as a young man—an interest which Mrs. Thaw and her family continued to show in subsequent years.

We mourn not only for an able executive and a man of the highest motives, but for a staunch personal friend and adviser, and a cheery companion.

MT. HAMILTON, CALIFORNIA,
1900 September 12.

ASTRONOMY*

DR. A. A. COMMON.

It has been decided to form a Department of Astronomy under Section A, and I have been requested to give an address on the occasion. In looking up the records of the British Association to see what position Astronomy has occupied, I was delighted to find in the very first volume, "A Report on the Progress of Astronomy during the Present Century," made by the late Sir George Airy, so many years our Astronomer Royal, and at that time Plumian Professor of Astronomy at Cambridge. This report, made at the second meeting of the Association, describes in a most interesting manner, the progress that was made during the first third of the century, and we can gather from it the state of astronomical matters at that time. The thought naturally occurred to me to give a report, on the same lines to the end of this century, but a little consideration showed that it was im-

* Opening Address by Dr. A. A. Common, F. R. S., F. R. A. S., Chairman of the Department of Astronomy, at the Bradford meeting of the British Association for the Advancement of Science.

possible in the limited time at my disposal to give more than a bare outline of the progress made.

At the time this report was written we may say, in a general way, that the astronomy of that day concerned itself with the position of the heavenly bodies only, and, except for the greater precision of observation resulting from better instruments and the larger number of observatories at work, this, the gravitational side of astronomy, remains much as it was in Airy's time.

What has been aptly called the New or Physical Astronomy did not then exist. I propose to briefly compare the state of things then existing with the present state of the science, without dealing very particularly with the various causes operating to produce the change; to allude briefly to the new astronomy; and to speak rather fully about astronomical instruments generally, and of the lines on which it is most probable that future developments will be made.

In this report (*Brit. Assoc. Report*, 1831-32, p. 125) we find that at the beginning of the century the Greenwich Observatory was the only one in which observations were made upon a regular system. The thirty-six stars selected by Dr. Maskelyne, and the Sun and the Moon, were observed on the meridian with great regularity, the planets very rarely and only at particular parts of their orbits; small stars, or stars not included in the thirty-six, were seldom observed.

This state of affairs was no doubt greatly improved at the epoch of the report, but it contrasts strongly with the present work at Greenwich, where 5,000 stars were observed in 1899, in addition to the astrographic, spectroscopic, magnetic, meteorological and other work.

Many observatories, of great importance since, were about that time founded, those at Cambridge, Cape of Good Hope and Paramatta having just been started. A list is given of the public observatories then existing, with the remark that the author is "unaware that there is any public Observatory in America, though there are," he says, "some able observers."

The progress made since then is truly remarkable. The first public Observatory in America was founded about the middle of the century, and now public and private observatories number about 150, while the instrumental equipment is in many cases superior to that of any other country. The prophetic opinion of Airy about American observers has been fully borne out. The discovery of two satellites to Mars by Hall in 1877, of a fifth

satellite to Jupiter by Barnard in 1892, and the discovery of Hyperion by Bond, simultaneous with Lassell, in 1848, are notable achievements.

The enormous amount of work turned out by the Harvard Observatory and its branches in South America, all the photographic and spectroscopic work carried out by many different astronomers, and the new lines of research initiated show an amount of enthusiasm not excelled by any other country. A greater portion of the astronomical work in America has been on the lines of the new astronomy, but the old astronomy has not been at all neglected. In this branch pace has been kept with other countries.

From this report we gather that the mural quadrant at most of the observatories was about to be replaced by the divided circle. Troughton had perfected a method of dividing circles, which, as the author says, "may be considered as the greatest improvement ever made in the art of instrument making."

Two refractors of 11 and 12-inches aperture had just been imported into this country; clockwork for driving had been applied to the Dorpat and Paris equatorials,but the author had not seen either in a state of action.

The method of mounting instruments adopted by the Germans was rather severely criticised by the author, the general principle of their mounting being "telescopes are always supported at the middle, not at the ends."

"Every part is, if possible, supported by counterpoises."

"To these principles everything is sacrificed. For instance, in an equatorial the polar axis to be supported in the middle by a counterpoise. This not only makes the instrument weak (as the axis must be single), but also introduces some inconvenience into the use of it. The telescope is on one side of the axis; on the other side is a counterpoise. Each end of the telescope has a counterpoise. A telescope thus mounted must, I should think, be very liable to tremor. If a person who is no mechanic and who has not used one of these intruments may presume to give an opinion, I should say that the Germans have made no improvement in instruments except in the excellence of the workmanship."

I have no doubt that this question had often occupied Airy's mind, for in the Northumberland Equatorial telescope which he designed shortly after for Cambridge he adopted what has been called the English form of mounting, where the telescope is supported by a pivot at each side, and a long polar axis is sup-

ported at each end. This telescope is in working order at the present time at Cambridge.

When he became Astronomer Royal he used the same design for what was for many years the great equatorial at Greenwich, though the wooden uprights forming the polar axis were in the Greenwich telescope replaced by iron. It says much for the excellence of the design and workmanship of this mounting, designed as it was for an object-glass of about 13 inches diameter, when we find the present Astronomer Royal, Mr. Christie, has used it to carry a telescope of 28 inches aperture, and that it does this perfectly.

Notwithstanding the greater steadiness of the English form of mounting, the German form has been adopted generally for the mounting of the large refractors recently made.

There is much interesting matter in this report of an historical character.

As I have already said, the New Astronomy, as we know it, did not exist; but in a report (*Brit. Assoc. Report*, 1831-32, p. 308) on optics, in the same volume, by Sir David Brewster, we find that spectrum analysis was then occupying attention, and the last paragraph of this report is well worth quoting: "But whatever hypothesis be destined to embrace and explain this class of phenomena, the fact which I have mentioned opens an extensive field of inquiry. By the aid of gaseous absorbent we may study with the minutest accuracy the action of the elements of material bodies in all their variety of combinations, upon definite and easily recognized rays of light, and we may discover curious analogies between their affinities and those which produce the fixed lines in the spectra of the stars. The apparatus, however, which is requisite to carry on such inquiries with success cannot be procured by individuals, and cannot even be used in ordinary apartments. Lenses of large diameter, accurate heliostats, and telescopes of large aperture are absolutely necessary for this purpose; but with such auxiliaries it would be easy to construct optical combinations, by which the defective rays in the spectra of all the fixed stars down to the tenth magnitude might be observed, and by which we might study the effects of the very combustion which lights up the suns of other systems."

Brewster's words are almost prophetic, and it would almost appear as if he unknowingly held the key to the elucidation of the spectrum lines, for it was not until 1859 that Kirchhoff's discovery of the true origin of the dark lines was made.

Fraunhofer was the first to observe the spectra of the planets and the stars, and to notice the different types of stellar spectra. In 1817 he recorded the spectrum of Venus and Sirius, and later, in 1823, he described the spectrum of Mars; also Castor, Pollux, Capella, Betelgeux and Procyon.

Fraunhofer, Lamont, Donati, Brewster, Stokes, Gladstone and others carried on their researches at a time when the principles of spectrum analysis were unknown, but immediately upon Kirchoff's discovery great interest was awakened.

With spectrum analysis thus established, aided as it was later by the greater development of photography, the New Astronomy was firmly established.

The memorable results arrived at by Kirchhoff were no sooner published than they were accepted without dissent. The works of Stokes, Foucault and Angström at that period were all suggestive of the truth, but do not mark an epoch of discovery.

Astronomical spectroscopy divided itself naturally into two main branches, the one of the Sun, the other of the stars, each having its many offshoots. I shall mention a few points relating to each. The dark lines in the solar spectrum had already been mapped by Fraunhofer, and now it only needed better instruments and the application of laboratory spectra with Kirchhoff's principle to advance this work still further.

Fraunhofer had already pointed out the way in using gratings and these were further improved by Nobert and Rutherfurd.

Kirchhoff's Map of the Solar Spectrum, published in 1861-62, was the most complete up to that time; but the scale of reference adopted by him was an arbitrary one so that it was not long before this was improved upon. Angström published in 1868 his map of the "Normal Solar Spectrum," adopting the natural scale of wave-lengths for reference, and this remained in use until quite recent times.

The increased accuracy in the ruling of gratings by Rutherfurd materially improved the efficiency of the solar spectroscope, but it was not until Prof. Rowland's invention of the concave grating that this work gained any decisive impetus. The maps (first published in 1885) and tables (published in the years 1896-98) of the lines of the solar spectrum are now almost universally accepted and adopted as a standard of reference. These tables alone record about 10,000 lines in the spectrum of the sun, which is in marked contrast to the number 7 recorded by Wollis-ton at the beginning of the century (1802). Good work in the

production of maps has also been done in this country by Higgs.

Michelson has also recently invented a new form of spectroscope called the "Echelon" (*Ast. Phys. Journal*, vol. viii, 1898, p. 37), in which a grating with a relatively small number of lines is employed, the dispersion necessary for modern work being obtained by using a high order (say the hundredth) into which most of the light has been concentrated.

Besides lines recorded in the visual and ultra-violet portions of the solar spectrum, maps have been made of the lines in the infra-red, the most important being that of Langley's published in 1894, prepared by the use of his "bolometer." Good work had, however, been done in this direction previously by Becquerel, Lamansky, and Abney;.the last, indeed, succeeded even in photographing a part of it.

The recording of the Fraunhofer lines in the solar spectrum is not all, however. The application of the spectroscope to the sun has several epoch marking events attached to it, notably those of proving the solar character of the prominences and corona, the rendering visible the prominences without the aid of an eclipse by the discovery of Lockyer and Jansen in 1868, the photography of the prominences both round the limb and those projected on the solar disc by the invention of the spectra-heliograph by Hale and Deslandres in 1890.

Success has not yet favored the many attempts to photograph the corona without an eclipse by spectroscopic means; but even now this problem is being attacked by Deslandres with the employment of calorific rays.

Spectroscopic work on the sun has led to the discovery of many hundreds of dark lines, the counterparts of which it has not yet been possible to produce on the earth.

But besides those unknown substances which reveal their presence by dark lines, there were two others discovered, which showed themselves only by bright lines, the one in the chromosphere, to which the name of Helium was given, and the other in the corona, to which the name of Coronium was applied.

The former was, however, identified terrestrially by Ramsay in 1895, though the latter is still undetermined. The revision of its wave-length, brought about by the observations of the eclipse of 1898, may, however, result in this element being transferred from the unknown to the known in the near future.

The study of stellar spectra was taken up by Huggins, Rutherford and Secchi. Rutherford (*Am. Journal*, vol. xxxv. 1862, p.

77) published in 1862 his results upon a number of stars, and suggested a rough classification of the white and yellow stars: but Secchi deserves the high credit of introducing the first systematic differentiation of the stars according to their spectra, he having begun a spectroscopic survey of the heavens for the purposes of classification (*Comptes rendus*, t. lvii. 1853), whilst Huggins devoted himself to the thorough analysis of the spectra of a few stars.

The introduction of photography marks another epoch in the study of stellar spectra. Sir William Huggins applied photography as early as 1863 (*Phil. Trans.* 1864, p. 428), 'and secured an impression of the spectrum of Sirius, but nearly another decade elapsed before Prof. H. Draper (*Am. Journal of Sci. and Arts*, vol. xviii, 1879, p. 421) took a photograph of the spectrum of Vega in 1872, which was the first to record any lines. With the introduction of dry plates this branch of the New Astronomy received another impetus, and catalogues of stellar spectra have now become numerous. Among them may be mentioned those of Harvard College, Potsdam, Lockyer, McClean and Huggins. The Draper Catalogue (*Annals Harvard Coll.*, vol. xxvii. 1890) of the Harvard College, which is a spectroscopic Durchmusterung, alone contains the spectra of 10351 stars down to the 7–8 magnitudes, and this has further been extended by work at Arequipa, whilst Vogel and Muller of Potsdam *Astro-Phys. Obs. zu Potsdam*, vol. iii 1882-83) made a spectroscopic survey of the stars down to the 7·5 magnitude between $-1°$ and $+20°$ declination. This has again been supplemented by Scheiner (*ibid.*, vol vii. 1895; "Untersuchungen uber die Spectra des hellerem Sterne"), and by Vogel and Wilsing (*ibid.*, vol. xii. 1899; "Untersuchungen uber die Spectra von 528 Sternen"). Lockyer (*Phil. Trans.*, vol. clxxxiv. A, 1893) in 1892 published a series of large scale photographs of the brighter stars, and more recently McClean (*Phil. Trans.*, vol. cxci. A, 1898) has conpleted a spectroscopic survey of the stars of both hemispheres down to the 3½ magnitude. For the study and investigation of special types of stars, the researches of Dunèr on the red stars, made at Upsala, and those of Keeler and Campbell on the bright-line stars, made at the Lick Observatory, deserve mention. For the study of stellar spectra the use of prisms in slit or objective-prism spectroscopes has predominated, though more recently the use of specially ruled gratings has been attended by some degree of success at the Yerkes Observatory.

Several new stars have also been discovered by their spectra by Pickering in his routine work of charting the spectra of the stars in different portions of the sky. The photographic plate containing their peculiar spectra was, however, not examined in many cases until the star had died down again.

Spectrum analysis also opened up another field of inquiry, viz., that of the motion of the stars in the line of sight, based on the process of reasoning due to Doppler, and accordingly named Doppler's Principle ("Ueber das farbige Licht der Doppelsterne," . . . *Abhandl. der K. Böhmischen Ges. d. Wiss.* V. Folge, 2 Bd. 1843).

The Observatories of Greenwich and Potsdam were among the first to apply this to the stars, and more recently Campbell at Lick, Newall at Cambridge, and Belopolsky at Pulkowa have made use of the same principle with enormous success.

It was also discovered that there are certain classes of stars having a large component velocity in the line of sight, which changes its direction from time to time, and in many such cases orbital motion has been proven, as in the case of Algol.

Another class of binary stars has also been discovered spectroscopically and explained by Doppler's principle. I refer to the stars known as spectroscopic binaries, in which the spectrum lines of one luminous source reciprocate over those from the other source of light, according as one is moving towards or away from the Earth. This displacement of the spectrum lines led to the discovery of the duplicity of β Aurigæ, and ζ Ursæ Majoris by Pickering (*Am. Jour.* [3], 39, p. 46, 1890).

Several other such stars have now been detected, notably β Lyræ, and lastly Capella, discovered independently by Campbell (*Astro-Phys. Jour.*, vol. x. p. 177) at Lick, and Newall (*Monthly Notice*, vol. lx. p. 2, 1899) at Cambridge.

(To be continued.)

ON THE ADJUSTMENT OF THE EQUATORIAL TELESCOPE.

FIRST PART.

KURT LAVES.

FOR POPULAR ASTRONOMY.

A relatively large number of amateur astronomers in the United States possess equatorials, which are mounted on piers and supplied with graduated circles. It is quite an easy task to put the

equatorial approximately into the meridian, and to place the polar axis at the proper elevation. It is more difficult to apply the final corrections, since they have to be derived from observations of stars, to be chosen advantageously from the list of Standard stars, published in the American Ephemeris and Nautical Almanac*. Still any one familiar with plane trigonometry and the use of logarithmic tables should be able to do this work satisfactorily. It is the purpose of this paper to furnish the proper directions in such an elementary fashion, as to keep within the prerequisites mentioned above, namely plane trigonometry and logarithms. In the first part of the paper the mathematical formulas will be derived; in the second part, to be published in a later issue, actual observations will be given and the methods will be explained in detail, of obtaining from them the values of the errors of the equatorial. It is advantageous to have a chronometer that keeps sidereal time, but if the observer has none, he may use instead a mean time chronometer, or a well regulated watch. In this case the additional work of transforming mean time into sidereal time will be necessary. A filar micrometer with position circle is not absolutely required for the work; a positive eyepiece with a pair of wires set perpendicular to each other and an incandescent lamp placed sidewise in front of the objective, will be all we need to point it to a star. He then selects an equatorial star in culmination and turns the eyepiece in the adapter so as to have one wire fall into the direction of the parallel; the other will then indicate the direction of the declination circle. The wires will appear as black lines on a white background, and care should be taken, that both the star and the wires appear clear and sharp to the observer; this is done by first focusing on the star and then shifting the eyepiece till the lines appear sharp. To avoid altering the position of the parallel a mark on the metal of the eyepiece and another on the adapter should be made when the parallel is determined.

We have now to develop the mathematical formulas, which will form the basis of our observatory work. The first three paragraphs are devoted to the development of the three fundamental formulas of spherical trigonometry.

§ 1. *Formulae of transformation for rectangular co-ordinates in the plane with the same origin.*

* The American Ephemeris is sold for one dollar. Application is to be made to "The Superintendent of the Nautical Almanac, Navy Department, Washington, D.C." To all places in the U. S. it is sent post free. Applicants from Canada have to add 30 cents to the price.

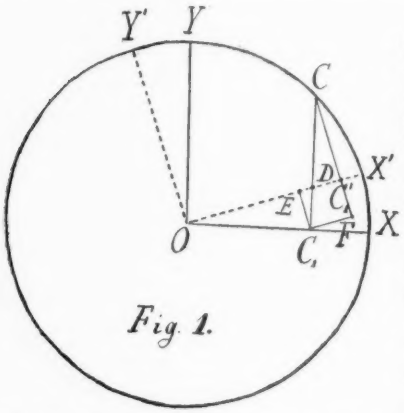


Fig. 1.

On a circle with radius r and center O we draw two radii perpendicular to each other OX and OY. Select a point C on the circumference between X and Y and let fall the perpendicular CC_1 on the line OX. We shall call OX and OY the X-axis and Y-axis respectively. The position of the axis being fixed, we see that OC_1 and C_1C will define the position of C in a definite manner so far as the quadrant XY is concerned. Let $OC_1 = x$ and $CC_1 = y$, and call x and y the rectangular coördinates of C. Now give to the axes OX and OY a common rotation through the angle φ so that they take the new positions OX' and OY'' respectively. The rectangular coördinates of C in this system are x' and y', $x' = OC'_1$ and $y' = CC'_1$. We shall now establish the following relations among the coördinates x', y' and x, y:

$$x' = x \cos \varphi + y \sin \varphi,$$
$$y' = -x \sin \varphi + y \cos \varphi.$$

Analytical Proof. Let us call the angle $COX = \psi$; then we have

$$x' = r \cos (\psi - \varphi) \text{ and } y' = r \sin (\psi - \varphi).$$

Expand $\cos (\psi - \varphi)$ and $\sin (\psi - \varphi)$ and we obtain:

$$x' = r \cos \varphi \cos \psi + r \sin \varphi \sin \psi;$$
$$y' = r \cos \varphi \sin \psi - r \sin \varphi \cos \psi;$$

since $r \cos \varphi = x$ and $r \sin \varphi = y$, we have our desired formulas at once.

Geometric Proof.—Draw C_1E perpendicular OX' then is $x' = OE + ED + DC_1'$ since angle $EOC_1 = \varphi$ and angle $EDC_1 =$ angle $CDC'_1 = 90 - \varphi$ we have $x' = OC_1 \cos \varphi + C_1D \sin \varphi + DC \sin \varphi = OC_1 \cos \varphi + (C_1D + DC) \sin \varphi$ or $x' = x \cos \varphi + y \sin \varphi$.

Similarly we have $y' = CF - C_1'F = CC_1 \cos \varphi - OC_1 \sin \varphi$, $y' = y \cos \varphi - x \sin \varphi$. Q. E. D.

§ 2. *Rectangular and Polar co-ordinates of a point in space.*

Let us now go over from the realm of two dimensions to that of three.

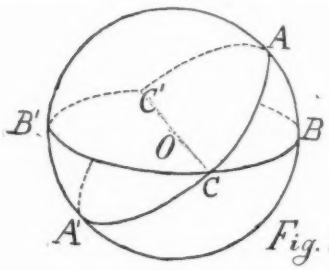


Fig. 2.

In figure 2, O is the center of a sphere, the radius of which we put equal to 1. Select three points A, B and C on its surface and pass three planes through O, the first containing A and B; the second B and C; and the third, C and A. The intersections of these planes with the surface of the sphere are great circles and by their mutual intersection in six points A, B, C and A', B', C' eight *spherical* triangles are formed on the surface. We shall limit our attention to the triangle ABC and we shall develop the three fundamental formulas in which the sin- and cosine-functions of the angles and sides will appear. Before doing this, we must acquaint ourselves with the meaning of the rectangular and polar coördinates of a point in space. To simplify matters let us use a square paper box as a model. Removing the cover we mark with ink the three inside edges which intersect each other under right angles in one corner. Call this corner O and select three points X, Y, Z on the three edges as indicated by figure 3; OX, OY, OZ will be referred to as the X-, Y- and Z-axes passing through the origin O. Stick a pin from above into the bottom of the box, so that it is parallel to the OZ-axis. Call the head of the pin C, and the foot point C_1. It is our purpose to describe in mathematical language the position of C so uniquely, that we may be able to find the point even when the pin is removed. To do this, we define first the position of C_1 by dropping the perpendiculars $C_1 C_2$ and $C_1 C_3$, the former one $C_1 C_2$, is the y coördinate of C_1 the latter, the x coördinate in the X Y-plane. Having defined C_1 we at once can find C, provided we know the distance $C_1 C = z$ measured from C_1 upward along a line perpendicular to the XY-plane. $C_1 C = z$, $C_1 C_2 = y$, $C_1 C_3 = x$ are called the *rectangular coordinates* of C.

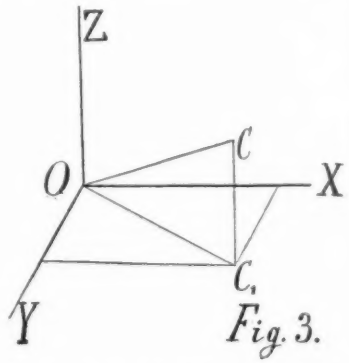


Fig. 3.

They suffice to define uniquely the position of C with respect to O, when we restrict our attention to that part of space which is limited by the lines X-, Y- and Z-axis in the directions from O to X, from O to Y, and from O to Z. The same result can be obtained by defining C by means of two angles φ and u and the distance of $OC = r$. The angles φ and u are defined as follows: pass a plane through C, O and Z, it will be perpendicular to the XY-plane. OC_1 is the projection of OC and we define φ as the angle which OC forms with its projection on the XY-plane. The angle is measured in the direction toward the OZ axis starting from the line OC_1. It is evident that φ lies between 0° and 90°. The angle u is the angle which the OX axis forms with the projection OC_1 measured in the direction from the X-axis to the Y-axis. With our restrictions we have u lying between 0° and 90°. r, φ, u are called the *polar coördinates* of C; it is obvious that by them C is uniquely defined. Since $z = CC_1 = OC \sin \varphi = r \sin \varphi$, and $OC_1 = r \cos \varphi$ we see at once that the relations among the rectangular and polar coördinates are as follows:

$$\begin{aligned} x &= r \cos \varphi \cos u, \\ y &= r \cos \varphi \sin u, \qquad \text{(a)} \\ z &= r \sin \varphi. \end{aligned}$$

It should be remarked, although we shall not make use of it, that these formulas hold generally for points located anywhere in space and not alone for points in that octant of space which we have considered. In this general case we have to distinguish between a positive and a negative direction of each axis and give to the rectangular coördinates the + or — sign according as they are measured on the positive or negative side of each axis. Similarly we have to extend the limit of φ and u; in the general case φ will vary between — 90° and + 90° and u can take any value from 0° to 360°.

§ 3. *The fundamental formulae of spherical trigonometry.*

In figure (4) AB is an arc of a great circle on the surface of a sphere with radius $OA = 1$. Select the radius OB as the $+Z$-axis of a system of three rectangular axes, passing through O. Let OX be the $+X$-axis; erect a perpendicular at O to the XZ-plane intersecting the hemisphere upon which C is located in Y; OY is the $+Y$-axis. The plane OXY intersects the surface of the sphere along the great circle XY. The plane OBC intersects the XY-plane in the line OC_1; OC_1 is the projection of OC on the XY-plane. Using our former symbols we have $r = 1$, $\varphi =$ angle C_1OC, $u = XOC_1$, the rectangular coördinates of C are x, y, z, and we have

$$x = 1.\cos\varphi.\cos u$$
$$y = 1.\cos\varphi.\sin u$$
$$z = 1.\sin\varphi$$

We now turn the X- and Z-axis around the $+$ Y-axis from the right to the left through the angle BOA which we call c. Then will the $+Z$-axis fall upon OA the $+$ X-axis will be directed to a point 90° distant from A. Let us distinguish the new positions from the old by calling the new axis OZ' and OX' respectively. The Y'-axis coincides with the Y-axis as remarked before. We have dotted the lines and circles in the new system in our figure. To find the coördinates x', y', z' of C in the new system we proceed as we did before. Plane OAC and plane $OY'X'$ intersect each other in the line OC_1', OC_1' being the projection of OC on the $X'Y'$-plane, angle $C_1'OC = \varphi'$, angle $X'OC_1' = u'$ therefore we have

$$x' = 1.\cos\varphi'.\cos u',$$
$$y' = 1.\cos\varphi'.\sin u',$$
$$z' = 1.\sin\varphi'.$$

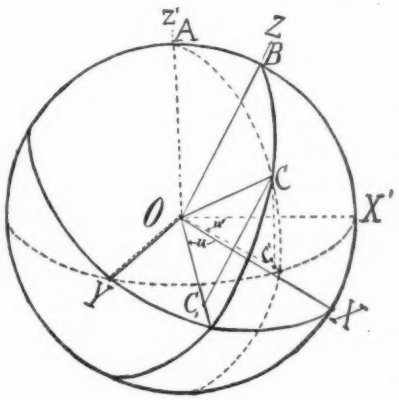


Fig. 4.

But we know from figure (4) that $y' = y$ since both are the projection of OC on the same axis, it is therefore but necessary to see how x', z' and x, z are related to each other. To establish these relations we need but make use of the theorem in § 1. Indeed in the OAB-plane we have two systems each of two rectangular axes, which are inclined to each other by the angle c. Therefore we have

$$x' = x\cos c + z\sin c,$$
$$z' = -x\sin c + z\cos c.$$

Introducing the polar coördinates we have the following system of equations

$$\cos\varphi'\sin u' = \cos\varphi\sin u,$$
$$\cos\varphi'\cos u' = \sin\varphi\sin c + \cos\varphi\cos c\cos u,$$
$$\sin\varphi' = \sin\varphi\cos c - \cos\varphi\sin c\cos u.$$

It is but necessary to identify u, φ, u', φ', c with the angles and sides of triangle ABC to obtain the desired result.

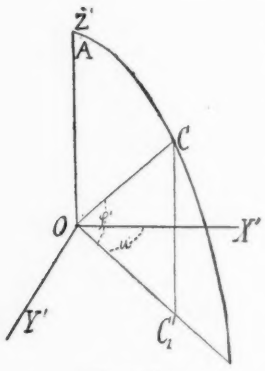


Fig. 5.

Let A, B, C designate the angles and a, b, c the sides of the triangle ABC. Since $BOC_1 = 90°$, and $C_1OC = \varphi$, therefore $90° - \varphi = a$. Since $AOC'_1 = 90°$ and $C_1'OC = \varphi'$, therefore $90° - \varphi' = b$. The plane angle $u = XOC_1$ is measured on the surface of the sphere by the arc of great circle contained between OX and OC_1, but this same arc measures as well as the angle CBX on the sphere which is $180 - B$, therefore we have $u = 180 - B$. In the same manner we obtain $u' = A$. Introducing the values of φ, u; φ', u' and c into our last equations and remembering that $\sin (180 - B) = \sin B$ $\cos (180 - B) = -\cos B$, $\sin (90 - a) = \cos a$, $\cos (90 - a) = \sin a$, we get:

$$\left.\begin{aligned} \sin b \sin A &= \sin a \sin B, \\ \sin b \cos A &= \cos a \sin c - \sin a \cos c \cos B, \\ \cos b &= \cos a \cos c + \sin a \sin b \cos B. \end{aligned}\right\} \text{(b)}$$

These are the three fundamental equations of spherical trigonometry.

§ 4. *The errors of the Equatorial Telescope.*

The characteristic features of an equatorial are:

(1) A system of two axes perpendicular to each other, one of which—the polar axis—is fixed, the other—the declination axis—can revolve about the first in a plane which is the instrumental equator. By means of a graduated circle, the hour angle circle, which lies in the plane of the instrumental equator the actual position of the declination axis in this plane can be ascertained.

(2) The telescope itself, fastened to one side of the declination axis and revolving about this axis. By means of a graduated circle, called the declination circle, fastened to the opposite side of the declination axis the actual position of the telescope, or more exactly that of the optical axis of the telescope, can be determined in the declination plane.

The zero point in the hour circle is very nearly the point where the projection of the south point upon the equator meets the equator. The angles measured by means of this circle are therefore hour angles and it is evident, that the hour angle of the declination axis will differ by very nearly 90° from that of the

object to which the telescope is directed. In the declination circle the angles are measured from the equator either upward to the North Pole or downward to the South Pole. The readings on both circles are effected by an index and the amount by which this is placed erroneously in position is the index error of the hour circle and declination circle respectivly. The first we shall designate later by $\triangle T$, the second by $\triangle D$. Let us suppose that the polar axis and the declination axis are both hollow tubes, which we may imagine to be transformed into small telescopes.

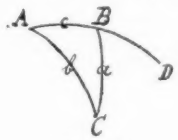


Fig. 6.

The objective of the polar axis will be on that end which is turned toward the North Pole, the objective of the declination axis telescope on that end where the circle is situated. Let π be the point in which the celestial sphere is pierced by the optical axis of the polar axis telescope, K the corresponding point for the declination axis telescope, and finally S the point to which the optical axis of the telescope itself is pointing. The spherical triangle πKS will then be the fundamental triangle for our later consideration. We shall call π the pole of the equatorial; it is obvious that under ideal conditions π would coincide with the celestial pole P. Designating the instrumental declination of the object S with d, we have $\pi S = 90 - d$, the instrumental declination of the point K will be called n, therefore $\pi K = 90 - n$. The angle measured by the arc KS is very nearly 90°; it is the angle which the optical axis of the telescope forms with that of the declination telescope. Let us put $KS = 90 + c$ and call the small quantity c the *error of collimation* of the telescope. πK and KS differing both from 90°, we cannot assume that the angle $K\pi S$ will be exactly $= 90°$. Let Q be the amount by which this angle differs from 90° and call $K\pi S = 90 + Q$. Evidently Q will depend upon c, n and d and we can easily determine Q in terms of these quantities. Applying the last equation of system (b) to our triangle πKS we obtain

$$\cos KS = \cos \pi K \cos \pi S + \sin \pi K \sin \pi S \cos K\pi S, \text{ or}$$
$$-\sin c = \sin n \sin d - \cos n \cos d \sin Q.$$

When an angle x is smaller than 15′ ($= 900''$) and we compute its log sin and log cos by means of a five place logarithm table, we may put $\sin x = x \sin 1''$ and $\cos x = 1$ without committing an error of one unit in the last place of each logarithm. The two quantities c and n will always be very much smaller than 15′ and we may therefore write $\sin Q = n \sin 1'' \operatorname{tg} d + c \sin 1'' \operatorname{tg} d$.

Except for a star, the polar distance of which is less than 1°, we may also put $\sin Q = Q \sin 1''$, so that we obtain
(*1*) $Q = n \operatorname{tg} d + c \sec d$. Of all the Nautical Almanac stars none has at present a polar distance less than 1°, so that we may safely employ this last simple equation for determining Q in terms of c, n and d.

The errors of the equatorial which we have so far discovered are the index errors $\triangle T$ of the hour circle and $\triangle D$ that of the declination circle, the collimation error c and the declination of the point K. We have mentioned that under ideal conditions π would coincide with P, but this will never be fufilled in reality. Referring the reader to figure 9 on Page 435 we observe that PZ is the ideal meridian, πZ the instrumental meridian. Calling πP (the arc between P and π) χ, it is obvious that the position of π with reference to P and the ideal meridian, will be defined by χ and the angle πPZ. If we drop a perpendicular from π upon the ideal meridian and call its foot point π°, we may as well define π by the two quantities $\pi\,\pi^\circ$ and $P\pi^\circ$; we shall call $\pi\,\pi^\circ$, η and $P\pi^\circ$, ξ. Then ξ and η are the rectangular coördinates of π with reference to a system of axis with origin at P, the $+ X$-axis of which is in the direction PZ, the $+ Y$-axis is in the 6^h circle and directed toward the west. The smaller χ, the nearer will ξ and η be represented by straight lines. The four quadrants around P will be numbered 1, 2, 3, 4 in the direction from PZ to the West, North, East and back to the South. In figure 9, π is therefore located in the fourth quadrant, ξ is a positive, and η a negative quantity. We are now going to show how the errors of the instrument and the quantities ξ and η are going to affect the declination and hour angle of a star. In order to have a complete enumeration of all the errors of the equatorial, the flexures of the telescope tube and of the polar and declination axes should be mentioned here. At present we disregard them, at the end of the next paragraph their effects upon the observations will be studied.

§ 5. *How to obtain the ideal hour angle τ and declination δ from the instrumental hour angle t and declination d.*

"Ideal hour angle" and "ideal declination" will be defined as the hour angle and declination as referred to the celestial pole P and meridian PZ, freed from the effect of refraction. The instrumental hour angle t and declination d are referred to the pole π and instrumental meridian πZ.

When we observe a star in the meridian, we can either place the tube of the telescope on the East or on the West side of the

pier. For stars in upper culmination the first position — telescope East — will mean that the declination axis is in the West, the second — telescope West — that the declination axis is in the East. Considering the apparent revolution of the sky the point K will in the first position precede the object, i. e., it will set before the object S does, in the second position K will follow S in the direction of daily rotation. For lower culmination the conditions are reversed. Indeed K being in the West as before, and the star in the North, it is obvious that K follows S, whereas when K is in the East K has attained a position to which S will come after about six hours. From these examples we see that without stating the particular position of the star, the remarks "circle preceding" or "circle following" will give us a unique definition of the relative position of K to S. In this way the observer, when discussing his observations, will at once be able to trace the fundamental triangle $K\pi S$ on the celestial sphere.

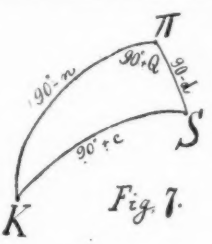


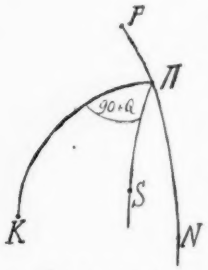
Fig. 7.

We shall designate the readings of the declination circle by D, and those of the hour angle circle by T. To distinguish the position "circle preceding" (*C. P.*) from that of "circle following" (*C. F.*) we shall use D' and T' for the readings in the first position, and D'' and T'' for those in to second position. The declination circle is generally divided in the four quadrants and the graduation runs from 0° to 90° in each quadrant, in the hour angle circle the graduation goes from 0^h to 24^h in the direction from the South to the West.

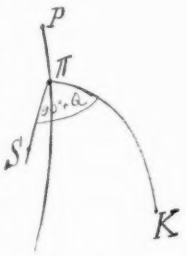
Assuming a positive index error, the instrumental declination in the position *C. P.* will be $d = D' + \Delta D$. Turning the telescope about the polar axis without loosening the declination clamp at first we reach the position *C. F.*, but to bring the telescope to the star again we have to turn it through the angle $2(90 - D)$, so that with a graduation from 0° to 180° we would directly read $180 - D$ in this position. This angle is too small by the amount ΔD as before and we obtain therefore $180 - d = 180 - D'' + \Delta D$ or since the graduation is supposed to run from 0 to 90

$$(2) \qquad \begin{aligned} d &= D'' - \Delta D \quad C.\,F. \\ d &= D' + \Delta D \quad C.\,P. \end{aligned}$$

from these two equations we obtain $d = \frac{D'' + D'}{2}$ and $\Delta D = \frac{D'' - D'}{2}$



Circle preceding.
Fig. 8a



Circle following.
Fig. 8b

Let us consider the corresponding equations in hour circle. In figures 8a and 8b we pass a great circle through P and π and to shorten our expressions we assume a point N on the prolongation of $P\pi$. Let the star S be on the west side of the instrumental meridian πZ. By means of the hour angle circle we can measure the hour angle $S\pi Z$ and derive from it and the errors of the instrument (including ξ and η among them) the ideal hour angle SPZ. In figure 8a we have

$$S\pi N = K\pi N - K\pi S = K\pi N - (90 + Q)$$

Let us imagine that the numbers of the hour angle circle be projected on the celestial sphere by radii drawn from the centre of the circles and prolongated till they meet the celestial sphere. Then the arc of great circle πK will intersect this great circle in a point the lettering of which may be designated by T' and the point where πN intersects it, will show a reading which we shall call T°. The angle $K\pi N$ is measured on the great circle and since the number increases from the meridian towards the west, we shall have $K\pi N = T' - T°$. We have therefore

$$S\pi N = T' - T° - (90 + Q). \qquad C.\ P.$$

In figure 8b we obtain

$$S\pi N = S\pi K - N\pi K = 90 + Q - (T° - T'').$$

The hour circle being graduated from 0^h to 24^h in the direction to the west starting from the instrumental meridian it is evident from what was said before, that the angle $N\pi K$ will be measured by $T° - T''$, ($T°$ will be very nearly 360° and T'' in our figure about 250°, so that $T'' - T° = 110°$ when we assume $S\pi N = 20°$).

For Q we have had [see formula (1)], $n \operatorname{tg} d + c \sec d$. Putting this into our equation we have

$$S\pi N = T' - T° - 90 - c \sec d - n \operatorname{tg} d \qquad C.\ P.$$
$$S\pi N = 90 - (T'' - T°) + c \sec d + n \operatorname{tg} d \qquad C.\ F.$$

But we do not want to refer S to the circle πN but to the instrumental meridian πZ. Call the angle $Z\pi N$, r measured around π

through the West, North, East to the line πN and subtract $360° - r$ from $S\pi N$ in both cases. We thus obtain $S\pi Z$, which is the instrumental hour angle, we shall designate it by t' and t'', the first one for *C. P.*, the second one for *C. F.* We obtain

$$(3)\qquad \begin{aligned} t' &= (T' - T^\circ - 90 + r) - c\sec d - n\,\mathrm{tg}\,d \qquad C.\,P. \\ t'' &= (90 - (T'' - T^\circ) + r) + c\sec d + n\,\mathrm{tg}\,d \qquad C.\,F. \end{aligned}$$

We have distinguished here between t' and t'' since the hour angle will change its value in the time required to reverse the telescope. In the equations (2) we have evidently $d = d' = d''$.

Having indicated how d and t can be obtained from the direct readings of the circles and the quantities c, n, r and ΔD we shall now show how from d, t, r and ξ and η the ideal coördinate and τ are determined.

In triangle $S\pi P$ we have $SP = 90 - \delta$, $S\pi = 90 - d$,
$P\pi = \chi$; $S\,\mathrm{angle}\,PZ = \tau$,

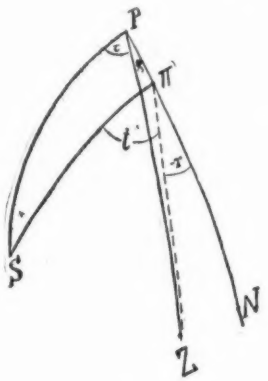


Fig. 9.

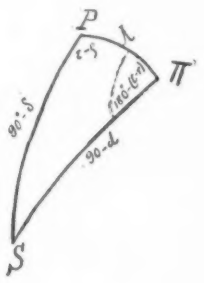


Fig. 10.

putting the angle $ZP\pi = \rho$ when measured around P in the direction West, North, East, we have $SP\pi = \tau - \rho$. The angle $S\pi P = r - 180 - t = 180 - (t - r)$. Applying formulas (*b*) to this triangle we get:

$$(4)\qquad \begin{aligned} \sin\delta &= \cos\chi \sin d - \sin\chi \cos d \cos(t - r), \\ \cos\delta \sin(\tau - \rho) &= \cos d \sin(t - r), \\ \cos\delta \cos(\tau - \rho) &= \sin d \sin\chi + \cos d \cos\chi \cos(t - r) \end{aligned}$$

Putting $\cos\chi = 1$, and $\sin\chi = \chi \sin 1''$, we have in the first equation $\sin\delta = \sin d - \chi \sin 1'' \cos d \cos(t - r)$.

Since $$\delta = \frac{\delta + d}{2} + \frac{\delta - d,}{2}$$

$$d = \frac{\delta + d}{2} - \frac{\delta - d,}{2}$$

we have $\sin \delta - \sin d = 2 \sin\left(\frac{\delta - d}{2}\right) \cos\left(\frac{\delta + d}{2}\right) =$

$$- \chi \sin 1'' \cos d \cos (t - r).$$

But $\cos \frac{\delta + d}{2} = \cos d$ .....

$2 \sin\left(\frac{\delta - d}{2}\right) = (\delta - d) \sin 1''$ and we obtain

(5.) $$\delta = d - \chi \cos (t - r).$$

To obtain an expression for $\tau - t$ from the last two equations of system (4) we must first find an expression for $\rho - r$. In the triangle $ZP\pi$ we have $ZP = 90 - \varphi$, where φ is the altitude o P, $Z\pi = 90 - f$, where f is the altitude of π, angle $P\pi Z = r - 180$ and angle $ZP\pi = 360° - \rho$.

The application of the first two equations of system (b) gives

$$\cos f \sin r = \cos \varphi \sin \rho,$$
$$- \cos f \cos r = \sin \varphi \sin \chi - \cos \varphi \cos \chi \cos \rho.$$

Forming the quotient of the two equations we get

$$- \frac{\cos r}{\sin r} = \operatorname{tg} \varphi . \frac{\sin \chi}{\sin \rho} - \cos \chi \frac{\cos \rho}{\sin \rho}, \text{ or}$$

$$- \cos r \sin \rho = \sin \chi \operatorname{tg} \varphi \sin r - \cos \chi \cos \rho . \sin r$$

or putting $\cos \chi = 1$ and $\sin \chi = \chi \sin 1''$ we obtain

$$\sin (\rho - r) = - \chi \sin 1'' \operatorname{tg} \varphi . \sin r \qquad \text{or}$$

(6.) $$\rho - r = - \chi \operatorname{tg} \varphi . \sin r. \quad .....$$

The last two equations under (4) can be transformed by elementary operations in such a manner that we finally get an equation for $\tau - t$; this will be

(7.) $$\tau - t = - \chi \operatorname{tg} \varphi . \sin r - \chi \operatorname{tg} d \sin (t - r).....$$

It will now depend which value of t we employ, that one for circle preceding or that for circle following, in the first case we get

$$\tau' = T' - T° - 90 + r - \chi \operatorname{tg} \varphi \sin r - c \sec d - n \operatorname{tg} d$$
$$- \chi \operatorname{tg} d \sin (t - r) \quad C. P. \text{ in the second case:}$$
$$\tau'' = 90° - (T'' - T°) + r - \chi \operatorname{tg} \varphi \sin r + c \sec d + n \operatorname{tg} d$$
$$- \chi \operatorname{tg} d \sin (t - r) \quad C. F.$$

(8.) Call $T' - T° - 90 + r - \chi \operatorname{tg} \varphi \sin r = T' + \Delta T$,
and $90 - (T' - T°) + r - \chi \operatorname{tg} \varphi \sin r = T'' + \Delta T$.

ΔT is the under error of the hour angle circle.

With these simplifications we write:

$$\tau' = T' + \Delta T - c \sec d - n \operatorname{tg} d - \chi \operatorname{tg} d \sin (t' - r) \qquad C.\ P.$$
$$\tau'' = T'' + \Delta T + c \sec d + n \operatorname{tg} d - \chi \operatorname{tg} d \sin (t'' - r) \qquad C.\ F.$$

$\chi \sin (t - r)$ we may replace by $\chi \sin (\tau - \rho) = \chi \sin \tau \cos \rho - \chi \cos \tau \sin \rho$. But $\chi \cos \rho = \xi$, and $\chi \sin \rho = \eta$; we have therefore $\chi \sin (\tau - \rho) = \xi \sin \tau - \eta \cos \tau$. Putting this into the last equations with the proper index in each case we have the equations in this final form:

$$\tau' = T' + \Delta T - c \sec d - n \operatorname{tg} d - \xi \sin \tau' \operatorname{tg} d + \eta \cos \tau \operatorname{tg} d \qquad C.\ P.$$
(9.)
$$\tau'' = T'' + c \sec d + n \operatorname{tg} d - \xi \sin \tau' \operatorname{tg} d + \eta \cos \tau \operatorname{tg} d \qquad C.\ F.$$

To obtain the equations for δ we put the values of d as given in system (2) into equation (5) and expand $\chi \cos (t - r)$ as before.

$$\delta = D' + \Delta D - \xi \cos \tau - \eta \sin \tau \qquad C.\ P.$$
(10)
$$\delta = D'' - \Delta D - \xi \cos \tau - \eta \sin \tau \qquad C.\ F.$$

We have so far neglected the effects of the flexures of the declination axis, the polar axis and the tube of the telescope upon the observations of a star. We shall call the maximum of flexure of the declination axis (when it is in horizontal position) E, the maximum of flexure of the tube of the telescope e and shall neglect the flexure of the short polar axis entirely. By elementary considerations like those given before, we can show that the equations for δ will have to be completed on the right side by a term $-e$ (sin f cos d — cos f sin d cos τ). The equations for τ will contain two additional terms namely:

$$\pm E (\sin f \operatorname{tg} d + \cos f \cos \tau) + e.\ \cos f.\ \sec d.\ \sin \tau$$

the upper sign of the first term to be used for *C. P.*, the lower sign for *C. F.*

THE UNIVERSITY OF CHICAGO.

1900 Sept. 15th.

TABLES FOR THE OBSERVATIONS OF EROS.

Bulletins No. 3 and 4 of the "Conference astrophotographique internationale" of July 1900, contain tables which are of great use to those who are taking part in the observation of Eros, for the purpose of determining the solar parallax. We take the

liberty of printing these tables in full.

1. The first is an ephemeris of Eros, calculated by M. Millosevich and interpolated for each day, to which has been applied the correction resulting from observations made at Paris on Aug. 4 and 7, 1900.

2. A table containing, for the region of the apparent path of Eros and for a width of about 2° 20′, the stars of reference whose positions it will be necessary to have determined by means of meridian instruments, in the largest possible number of observations. In accordance with the desire expressed by the conference, this table has been constructed in such a manner that one may select about twelve stars of reference for computing the constants of each plate, in the new series of photographs to be obtained by means of the instruments designed for the photographic chart of the heavens.

3. A table giving approximately the local time at the two moments when Eros is 20° above the horizon.

4. A table giving the equatorial coördinates of points 1° apart, within a half minute of arc, upon the apparent trajectory of Eros. These coördinates may be adopted as the centers of photographic plates designed for furnishing the relative positions of the comparison stars.

For the purpose of obtaining the greatest homogeneity in the construction of the photographic catalogue of the heavens, the conference decided that stars of reference should be referred to Newcomb's Catalogue of Fundamental Stars. The president of the conference, Mr. Loewy, suggests that it would be well to adopt the same rule with reference to the comparison stars for Eros.

EPHEMERIS OF EROS FOR 12^h BERLIN MEAN TIME.

Dates.	R. A. (true) h m s	Dec. (true) ° ′	log *r*.	log Δ.	Par. ″
1900. Sept. 19	2.39. 3	+40.24,2	0,1669	9,8182	13,4
20	39.43	40.47,1			
21	40.20	41. 9,9			
22	40.55	41.32,8			
23	41.27	41.55,7			
24	41.56	42.18,6			
25	42.23	42.41,4			
26	42.46	43. 4,2			
27	43. 7	43.27,0			
28	43.25	43.49,7			
29	43.40	44.12,3	0,1574	9,7663	15,1
30	43.51	44.34,8			
Oct. 1	44. 0	44.57,2			
2	44. 6	45.19,6			
3	44. 7	45.41,8			
24	2.44. 4	+46. 3,8			

EPHEMERIS OF EROS FOR 12h BERLIN MEAN TIME.

Dates.		R. A. (true)	Dec. (true)	log r.	log Δ.	Par.
		h m s	° ′			
1900, Oct.	5	2.43.58	+46.25,7			
	6	43.50	46.47,5			
	7	43.37	47. 9.0			
	8	43.20	47.30,3			
	9	42.58	47.51,4	0,1475	9,7149	17,0
	10	42.33	48.12,3			
	11	42. 4	48.32,9			
	12	41.31	48.53,2			
	13	40.53	49.13,2			
	14	40.11	49.32,8			
	15	39.24	49.52,0			
	16	38.32	50.10,8			
	17	37.36	50.29,2			
	18	36.36	50.47,2			
	19	35.31	51. 4,6	0,1373	9,6654	19,0
	20	34.21	51.21,5			
	21	33. 7	51.37,8			
	22	31.48	51.53,6			
	23	30.25	52. 8,7			
	24	28.58	52.23,1			
	25	27.27	52.36,8			
	26	25.52	52.49,8			
	27	24.13	53. 2,1			
	28	22.30	53.13,6			"
	29	20.44	53.24,2	0,1269	9,6199	21,1
	30	18.55	53.34,0			
	31	17. 2	53.43,0			
Nov.	1	15. 8	53.51,1			
	2	13.11	53.58,3			
	3	11.12	54. 4,5			
	4	9.11	54. 9,8			
	5	7. 9	54.14,1			
	6	5. 7	54.17,5			
	7	3. 4	54.19,8			
	8	2. 1. 0	54.21,1	0,1165	9,5804	23,1
	9	1.58.56	54.21,4			
	10	56.53	54.20,7			
	11	54.51	54.18,9			
	12	52.50	54.16,1			
	13	50.51	54.12,3			
	14	48.54	54. 7,4			
	15	47. 0	54. 1,4			
	16	45. 9	53.54,5			
	17	43.22	53.46,6			
	18	41.38	53.37,7	0,1061	9,5484	24,9
	19	39.59	53.27,8			
	20	38.24	53.17,0			
	21	36.54	53. 5,2			
	22	35.30	52.52,6			
	23	34.11	52.39,1			
	24	32.57	52.24,7			
	25	31.50	52. 9,6			
	26	30.48	51.53,7			
	27	29.53	51.37,0			
	28	29. 5	51.19,7	0,0961	9,5248	26,3
	29	28.23	51. 1,7			
	30	27.48	50.43,0			
Dec.	1	1.27.20	+50.23,8			

EPHEMERIS OF EROS FOR 12h BERLIN MEAN TIME.

Dates.	R. A. (true)	Dec. (true)	log r.	log Δ.	Par.
	h m s	° ′			
1900. Dec. 2	1.26.59	+50. 4,0			
3	26.43	49.43 7			
4	26.35	49.22 9			
5	26.33	49. 1,7			
6	26.39	48.40 0			
7	26.50	48.17.9			″
8	27. 9	47.55 4	0,0865	9,5092	27,3
9	27.34	47.32 5			
10	28. 5	47. 9,3			
11	28.44	46.45 7			
12	29.28	46.21.9			
13	30.18	45.57.8			
14	31.15	45.33.5			
15	32.18	45. 9,0			
16	33.26	44.44 3			
17	34.41	44.19 4			
18	36. 1	43.54 3	0,0778	9,5008	27,8
19	37.28	43.29,1			
20	38.59	43. 3,8			
21	40.36	42.38 3			
22	42.19	42.12 8			
23	44. 7	41.47.2			
24	46. 1	41.21.5			
25	47.59	40.55.8			
26	50. 1	40.30 0			
27	52. 9	40. 4 2			
28	54.21	39.38.4	0,0700	9,4990	27,9
29	56.38	39.12,6			
30	1.58.58	38.46,8			
31	2. 1.23	38.21,0			
1901. Jan. 1	3.53	37.55 2			
2	6.26	37.29 4			
3	9. 3	37. 3 6			
4	11.43	36.37 8			
5	14.27	36.12,1			
6	17.14	35.46 3			
7	2.20. 5	+35.20,6	0,0636	9,5029	27,6

Comparison Stars for Observations of Eros.

No.	Mag.	R. A. 1900,0.	Dec. 1900,0.	No.	Mag.	R. A. 1900,0.	Dec. 1900,0.
°		h m s	° ′	°		h m s	° ′
399 BD +49	8,6	1.24. 0	+49.25,5	442BD +47	9,3	1.26.17	+47.54,2
370 +46	6,0	24. 6	46.29,5	299 +50	8,8	26.23	50.18,6
317 +51	8,9	24.26	51.34,7	300 +50	9,5	26.48	50.57,9
400 +49	9,5	24.33	50. 5,6	301 +50	9,3	26.59	50.22,4
429 +47	8,5	24.33	47.22,9	463 +48	8,7	27.16	48.30,3
401 +49	8.5	24.38	50. 9,2	412 +49	9,3	27.49	49.37,0
373 +46	8,1	24.48	47. 3,1	331 +51	8,6	27.59	51.19,3
403 +49	9,1	24.51	49.54,9	376 +45	8,9	28. 0	45.27,8
434 +47	9,5	24.51	47.54,1	450 +47	8,9	28. 5	47.54,5
453 +48	7,1	24.54	48.49,8	414 +49	9,3	28.19	50. 1,1
454 +48	9,0	25.26	48.31 5	470 +48	7,6	28.20	49. 3,1
455 +48	9,1	25.26	48.16,3	334 +51	9,0	28.33	51.38,5
297 +50	9,5	25.42	50.56,5	379 +45	9,0	28.33	46. 0,8
323 +51	7,8	25.46	51.57,3	326 +44	8,8	28.38	45. 5,0
298 +50	9,5	1.26.10	+50.38,6	383 +45	9,0	1.29.16	+45.19,0

COMPARISON STARS FOR OBSERVATIONS OF EROS.

No.		Mag.	R. A. 1900,0.	Dec. 1900,0.	No.		Mag.	R. A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
338 BD	+51	7,4	1.29.22	+51.39,2	386 BD	+53	7,6	1.41.15	+53.30,3
329	+44	8,5	29.20	44.24,9	373	+42	7,9	41.25	42.34,9
389	+46	8,3	29.30	46.22,9	388	+53	8,3	41.35	53.23,4
393	+46	7,4	29.59	46.36,2	347	+41	8,7	41.45	41.55,4
416	+49	9,1	30. 3	50.11,7	441	+52	8,3	41.53	52.45,0
477	+48	8,7	30. 3	48.41,6	375	+42	8,9	41.56	42.42,8
397	+46	7,0	30.19	46.48,9	383	+54	8,6	42.39	54.38,6
460	+47	6,6	30.20	48.12,7	352	+41	9,1	42.55	42.12,6
339	+51	7,6	30.24	51.14,3	373	+43	8,6	43.11	43.14,3
462	+47	7,3	30.33	47.33,8	395	+53	8,6	43.11	53.25,0
387	+52	8,5	30.39	52.35,8	353	+41	8,5	43.14	41.29,5
463	+47	7,5	30.40	47.48,3	388	+54	7,9	43.57	54.43,3
314	+50	8,7	30.44	50.45,0	398	+53	8,4	44. 0	53.14,8
418	+49	9,5	30.55	49.26,4	392	+54	8,0	44.42	54.54,6
344	+51	9,2	31. 9	52. 7,3	393	+54	7,3	44.53	54.25,8
404	+46	7,8	31.13	46.26,3	388	+42	8,0	45. 3	43. 1,8
392	+45	7,8	31.14	45.57,0	402	+53	8,7	45.11	53.22,3
394	+45	8,7	31.25	45.26,9	390	+42	8,5	45.22	42.16,1
422	+49	8,8	31.42	50. 5,8	396	+54	6,1	45.25	54.39,2
335	+44	8,7	32. 5	44.18,5	384	+40	9,2	45.37	40.57,6
337	+44	8,1	32.21	45. 9,3	421	+39	8,8	46.25	40. 3,2
398	+45	8,4	32.22	45.55,2	362	+41	8,2	46.43	41.20,9
341	+44	7,4	32.30	44.53,5	390	+40	8,2	46.49	40.59,5
393	+52	8,6	32.31	52.43,9	364	+41	9,0	47.10	42. 2,3
337	+43	8,1	32.40	43.38,2	408	+54	6,8	47.11	55. 6,3
355	+53	8,4	33. 4	53.37,6	394	+40	6,2	47.17	40.14,2
341	+43	8,8	33.10	43.31,6	416	+53	8,4	48. 7	53.24,0
399	+52	8,1	33.13	52.24,5	413	+54	9,0	48.13	54.14,2
357	+51	7,7	33.13	51.45,6	419	+53	7,4	48.25	53.41,8
343	+43	5,5	33.21	43.52,7	400	+40	8,5	48.27	40.23,9
360	+51	7,6	33.34	52. 8,4	431	+39	7,4	48.37	40. 9,9
321	+41	8,7	33.41	42.13,9	401	+40	8,9	48.39	41. 9,0
363	+53	6,8	33.50	53.21,7	434	+39	6.9	48.53	40.12,8
363	+51	8,1	34. 2	51.21,5	415	+54	8.0	49. 8	55. 5,2
364	+51	8,6	34.10	52. 1,4	440	+55	8,0	4 9.14	55.20,2
346	+44	9,0	34.45	44.16,5	417	+54	8,4	49.31	55.10,0
347	+44	8,4	34.48	44.30,8	374	+41	7,4	50.28	41.24,2
416	+45	9,0	35.22	45.54,4	377	+41	8,2	51.10	41.16,7
406	+52	8,7	35.23	52.52,3	424	+54	9,1	51.13	54.52,9
352	+44	8,0	35.51	45. 4,3	406	+40	8,9	51.14	40.16,3
351	+42	9,1	35.58	42.21,5	428	+53	8,8	51.36	54. 7,2
352	+42	7,0	36. 4	43. 8,1	429	+54	7,8	52.10	55. 5,7
354	+42	8,6	36.16	42.31,0	412	+40	8,3	52.20	40.25,6
329	+41	8,5	36.17	41.25 5	447	+39	8,5	52.22	40. 3,1
422	+45	9,0	36.24	45.32,2	464	+55	8,2	52.51	55.18,0
424	+45	8,8	37. 4	45.26,2	431	+54	8,7	52.56	54.20,2
354	+44	7,0	37.11	44.49,1	448	+39	8,2	53.36	40. 4,7
356	+42	8,8	37.17	43.12,0	415	+40	7,5	53.39	40.51,9
420	+52	7,0	37.17	52.22,9	452	+37	7.4	54.18	38. 6,8
375	+53	8,8	37.25	53.26,7	450	+39	7,9	54.29	39.29,0
368	+54	7,0	37.47	54.23,0	421	+40	7,1	54.41	40.52,6
424	+52	8,3	37.58	52.41,2	392	+38	7,8	54.48	39. 7,4
360	+42	7,6	38. 5	42.44,3	423	+40	7,3	55. 9	40.43,7
361	+42	8,2	38.13	43. 8,7	437	+53	8,9	55.22	53.32,0
433	+52	8,6	39.43	53. 6,4	439	+53	5,4	55.38	54. 0,3
364	+43	8,5	40.15	44. 8,8	454	+39	8,6	55.45	40.11,1
370	+42	8,6	40.17	43.12,3	444	+54	8,0	56.26	54.45,0
364	+40	7,8	40.37	41. 3,1	465	+37	8,1	56.38	38. 3,7
342	+41	8,8	1.41.11	+41.41,7	440	+53	7,6	1.56.45	+54.12,8

Comparison Stars for Observations of Eros.

No.		Mag.	R. A. 1900,0	Dec. 1900,0.
	°		h m s	° ′
484	BD +55	8,6	1.57. 4	+55.17,2
468	+37	8,7	57. 5	38. 9,9
448	+54	9,0	57. 6	54.38,4
457	+39	9,1	57.45	39.34,5
452	+54	8,0	57.58	54.16,6
453	+54	6,6	58.17	55. 8,6
402	+38	8,0	58.43	38.57,3
457	+54	9,0	59. 8	54.27,0
464	+39	7,8	1.59.43	39.16,9
451	+53	8,2	2. 0. 2	53.49,8
408	+38	8,2	0.22	38.25,3
468	+39	8,5	0.30	40. 7,3
453	+53	8,5	1.36	54. 7,7
486	+37	5,0	2.26	37.23,1
527	+55	9,1	2.48	55.22,8
416	+38	7,3	2.49	38.52,4
488	+37	8,6	2.54	38. 3,4
469	+54	8,8	3. 9	55. 0,8
459	+53	8,2	3.21	53.51,5
460	+53	6,2	3.24	53.22,3
470	+54	8,9	3.28	54.49,2
470	+53	8,5	4.59	54. 4,8
483	+54	8,7	6.11	54.38,5
474	+53	8,2	6.26	53.45,0
494	+54	7,5	7.42	54.51,0
485	+53	9,0	7.57	53.34,5
486	+53	7,8	8. 5	54. 3,9
551	+55	8,1	8. 6	55.16,8
497	+54	7,1	8.17	54.37,3
549	+52	8,4	8.28	53. 6,7
500	+54	7,9	8.34	55. 7,7
494	+53	8,6	11. 6	54. 0,1
511	+54	8,6	11.35	55. 4,7
497	+53	7,8	11.34	53.49,0
501	+53	8,7	12. 6	53.38,0
563	+52	8,5	12. 6	53. 6,9
525	+54	6,5	14. 4	54.56,9
507	+53	6,0	14.20	54. 3,1
513	+53	8,8	14.54	53.47,5
530	+54	9,2	15.44	54.37,4
535	+54	6,2	16.54	54.54,6
519	+53	8,4	17.20	53.44,2
521	+53	8,4	17.29	53.19,2
576	+52	8,8	17.35	52.59,6
539	+54	7,6	18.14	54.48,1
580	+52	8,7	19. 3	52.55,0
525	+53	8,4	19.30	53.40,5
581	+52	8,7	20.30	53. 3,0
554	+54	8,4	21.46	54.31,6
585	+52	9,2	21.54	53. 5,6
587	+52	8,5	22.52	52.36,9
532	+53	8,2	23. 5	53.24,4
565	+54	8,5	24.33	54.27,1
587	+51	9,2	24.57	51.51,8
592	+52	8,3	25. 3	52.23,5
539	+53	8,8	25.30	53.52,0
540	+53	9,3	25.49	53.32,1
541	+53	7,2	25.55	54. 6,2
595	+52	8,6	2.27.16	+52.23,5
597	BD +52	8.8	2.27.23	+52.57.9
594	+51	8,8	27.40	51.32,0
587	+50	9,1	28.24	50.45,1
546	+53	8,8	28.31	53.15,0
547	+53	8.4	28.34	53.52,7
598	+51	8,0	29.15	52. 3.0
599	+51	7,1	29.56	51.31,5
602	+52	8,7	30.52	52.22,7
589	+50	8,6	31.23	50.26,1
604	+51	9,0	31.37	51.38.7
595	+50	8,5	32.25	50.21,1
733	+49	8,9	32.49	50. 5,3
609	+52	7,6	33.23	52.22,4
601	+50	8,4	33.42	51.11,6
567	+40	8,7	34.12	40.53,2
741	+49	9,3	34.18	49.35.0
743	+49	9,1	34.25	49.41,4
616	+51	8,8	35.21	52. 0,4
609	+39	9,0	35.38	40. 4,7
570	+40	7,5	35.38	40.58,0
618	+51	9,1	35.39	51.28,5
517	+41	8,2	35.47	41.44,9
616	+52	6,2	35.56	53. 6,0
617	+52	9,2	36.20	52.19,8
610	+42	8,4	36.34	42.35,1
620	+51	9,6	36.38	51.59,3
613	+50	8,4	36.40	51. 6,5
752	+49	8,6	36.46	49.57,6
753	+49	9,3	36.48	50.10,3
613	+42	8,6	37. 5	42.46,9
614	+42	7,3	37. 6	43. 6,8
615	+42	8,8	37. 6	42.11,8
577	+40	7,5	37.21	41. 4,4
746	+48	4,0	37.21	48.48,4
617	+50	8,9	37.24	50.48,0
566	+43	6,5	37.34	43.52,3
581	+40	9,0	37.53	40.21,6
622	+46	7.9	37.53	46.25.3
582	+40	8,6	37.56	40.41,0
620	+50	8,4	38. 5	50.18,3
569	+44	8.1	38.12	45.10,6
623	+50	8.8	38.33	51. 9,8
750	+48	8,3	38.56	48.32,2
692	+47	8,3	38.58	47.43.3
530	+41	8,6	39.12	42. 6.3
628	+46	9,0	39.23	46.48,7
627	+50	8,4	39.29	50.11,8
589	+40	8,0	39.29	40.29.4
752	+48	9,0	39.35	48.56,4
628	+39	7.9	39.38	40.11,5
573	+44	8,5	39.44	45. 1,8
590	+40	8,8	39.47	41. 2,4
626	+51	9,0	39.53	51.47,1
574	+43	7,9	40. 1	43.20,7
628	+51	8,9	40. 7	51.43,7
660	+45	7,2	40.34	45.29,8
538	+41	8,0	40.42	41.45,3
628	+42	7,6	40.53	42.59,0
576	+43	7,0	2.40.59	+43.51,2

COMPARISON STARS FOR OBSERVATIONS OF EROS.

No.		Mag.	R. A. 1900,0.	Dec. 1900,0.	No.		Mag.	R A. 1900,0.	Dec. 1900,0.
	°		h m s	° ′		°		h m s	° ′
577	BD +44	8,8	2.41. 1	+44.50,8	610	BD +40	8,5	2.43.51	+40.24,3
773	+49	9,1	41. 5	49.39,6	711	+47	7,9	43.53	47.52,6
630	+50	7,9	41. 6	51. 8,0	665	+45	8,8	44. 0	45.25,4
698	+47	8,4	41.20	47.46,7	612	+40	9,3	44. 6	40.53,0
760	+48	8,9	41.25	48.48,1	638	+42	7,6	44. 6	42.54,0
541	+41	9,0	41.26	41.27,0	550	+41	8,7	44. 7	41.31,8
636	+50	7,6	41.36	50.28,8	586	+43	8,7	44. 7	43.56,7
700	+47	8,3	41.43	48. 2,2	667	+45	8,2	44. 9	45.39,5
579	+43	7.5	41.43	43.12,3	770	+48	8,7	44.20	48.56,2
638	+46	8,7	41.50	46.32,8	714	+47	8,3	44.40	48. 5,6
762	+48	8.0	42. 1	48.46,0	669	+45	8,4	44.54	45.34,6
602	+40	8,8	42. 4	40.33,7	648	+46	6,4	45. 0	46.25,8
543	+41	8,8	42.12	41.59,9	591	+44	7,8	45. 7	44.38,8
633	+42	8,9	42.13	42.18,9	593	+44	7,0	45.17	44.28,9
702	+47	8,0	42.19	47.12,6	777	+48	8,3	45.20	48.28,3
763	+48	8,4	42.27	48.53,1	720	+47	9,1	45.37	47.30,1
641	+46	7,5	42.28	46.48,1	782	+48	8,9	45.39	49. 5.4
633	+51	8,6	42.28	51.13,6	721	+47	8,5	45.51	48. 0,5
580	+43	9,0	42.35	43.53,9	593	+43	8,8	45.53	43.21,7
764	+48	8,6	42.43	48.27,8	556	+41	7,2	45.54	41.36,6
662	+45	8,2	42.55	45.59,2	643	+42	9,1	46. 6	42.21,5
782	+49	9,0	42.59	49.35,9	652	+46	7,4	47.16	46.45,2
582	+44	8,6	43. 5	44.59,3	650	+42	8,9	48.26	42.48,4
709	+47	7,7	43.21	47.43,9	656	+46	7,3	48.48	46.53,9
583	+43	8,9	43.26	43.23,9	679	+45	8,7	49.15	45.26,1
637	+42	9,1	43.27	42.23,1	598	+44	8,9	2.49.29	+44.34,7
644	+46	9,2	2.43.34	+46.59,9					

Table giving, in mean time, the approximate limits between which the altitude of Eros above the horizon is greater than 20° for the dates and latitudes indicated.

°	Oct. 9.			Oct. 19.			Oct. 29.		
	h m		h m	h m		h m	h m		h m
36.....	6.51	to	20. 9	5.52	to	19.34	4.47	to	18.51
37.....	6.46		20.14	5.46		19.40	4.41		18.57
38.....	6.41		20.19	5.40		19.46	4.34		19. 4
39.....	6.36		20.24	5.34		19.52	4.27		19.11
40.....	6.30		20.30	5.28		19.58	4.20		19.18
41.....	6.25		20.35	5.21		20. 5	4.13		19.25
42.....	6.19		20.41	5.14		20.12	4. 5		19.33
43.....	6.13		20.47	5. 7		20.19	3.57		19.41
44.....	6. 7		20.53	4.59		20.27	3.49		19.49
45.....	6. 1		20.59	4.51		20.35	3.40		19.58
46.....	5.54		21. 6	4.43		20.43	3.31		20. 7
47.....	5.47		21.13	4.35		20.51	3.21		20.17
48.....	5.40		21.20	4.27		20.59	3.11		20.27
49.....	5.32		21.28	4.18		21. 8	2.59		20.39
50.....	5.24		21.36	4. 8		21.18	2.47		20.51
51.....	5.16		21.44	3.57		21.29	2.34		21. 4
52.....	5. 7		21.53	3.46		21.40	2.21		21.17
53.....	4.57		22. 3	3.34		21.52	2. 2		21.36
54.....	4.47		22.13	3.19		22. 7	1.39		21.59
55.....	4.36		22.24	3. 3		22.23	1.14		22.24
56.....	4.26		22.34	2.46		22.40	0.47		22.51
57.....	4.12		22.48	2.23		23. 3	—		—
58.....	3.56		23. 4	1.55		23.31	—		—
59.....	3.39		23.21	—		—	—		—
60.....	3.19		23.41	—		—	—		—
Meridian Passage at Paris	13^h30^m			12^h43^m			11^h49^m		

Table giving, in mean time, the approximate limits between which the altitude of Eros above the horizon is greater than 20° for the dates and latitudes indicated.

	Nov. 8.		Nov. 18.		Nov. 28.		Dec. 8.		Dec. 18.		Dec. 28.	
°	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
36...	3.44	17.56	2.49	16.53	2. 7	15.53	1.40	14.58	1.23	14.13	1.16	13.38
37...	3.37	18. 3	2.42	17. 0	2. 1	15.59	1.35	15. 3	1.19	14.17	1.13	13.41
38...	3.30	18.10	2.35	17. 7	1.55	16. 5	1.30	15. 8	1.15	14.21	1. 9	13.45
39...	3.23	18.17	2.28	17.14	1.49	16.11	1.25	15.13	1.11	14.25	1. 5	13.49
40...	3.16	18.24	2.21	17.21	1.43	16.17	1.19	15.19	1. 6	14.30	1. 1	13.53
41..	3. 8	18.32	2.14	17.28	1.36	16.24	1.13	15.25	1. 1	14.35	0.57	13.57
42...	3. 0	18.40	2. 6	17.36	1.29	16.31	1. 7	15.31	0.56	14.40	0.54	14. 0
43...	2.52	18.48	1.58	17.44	1.22	16.38	1. 1	15.37	0.51	14.45	0.50	14. 4
44...	2.43	18.57	1.50	17.52	1.14	16.46	0.55	15.43	0.46	14.50	0.46	14. 8
45...	2.34	19. 6	1.41	18. 1	1. 6	16.54	0.49	15.49	0.41	14.55	0.42	14.12
46...	2.24	19.16	1.32	18.10	0.58	17. 2	0.42	15.56	0.36	15. 0	0.38	14.16
47...	2.14	19.26	1.22	18.20	0.50	17.10	0.36	16. 2	0.30	15. 6	0.34	14.20
48...	2. 3	19.37	1.11	18.31	0.42	17.18	0.29	16. 9	0.24	15.12	0.29	14.25
49...	1.51	19.49	0.59	18.43	0.32	17.28	0.21	16.17	0.18	15.18	0.24	14.30
50...	1.37	20. 3	0.48	18.54	0.22	17.38	0.13	16.25	0.12	15.24	0.19	14.35
51...	1.22	20.18	0.35	19. 7	0.11	17.49	0. 5	16.33	0. 6	15.30	0.14	14.40
52...	1. 7	20.33	0.20	19.22	0. 1	17.59	−0. 4	16.42	−0. 1	15.37	0. 8	14.46
53...	0.45	20.55	−0. 1	19.43	−0.13	18.13	−0.14	16.52	−0. 8	15.44	0. 3	14.51
54...	0.20	21.20	−0.25	20. 7	−0.28	18.28	−0.24	17. 2	−0.16	15.52	−0. 3	14.57
55...	−0. 9	21.49	−0.52	20.34	−0.44	18.44	−0.35	17.13	−0.24	16. 0	−0. 9	15. 3
56...	—	—	−1.21	21. 3	−1. 2	19. 2	−0.46	17.24	−0.33	16. 9	−0.15	15. 9
57...	—	—	—	—	−1.27	19.27	−1. 1	17.39	−0.43	16.19	−0.22	15.16
58...	—	—	—	—	−1.57	19.57	−1.17	17.55	−0.53	16.29	−0.29	15.23
59...	—	—	—	—	—	—	−1.35	18.13	−1. 4	16.40	−0.37	15.31
60...	—	—	—	—	—	—	−1.55	18.33	−1.14	16.50	−0.45	15.39
Meridian Passage at Paris	$10^h.50^m$		$9^h.51^m$		$9^h.0^m$		$8^h.19^m$		$7^h.48^m$		$7^h.27^m$	

SUCCESSIVE POINTS ON THE APPARENT PATH OF EROS, ONE DEGREE OF ARC APART.

Dates.	R. A.	Decl.	Dates.	R. A.	Decl.
	h m s	° ′		h m s	° ′
Sept. 19.50	2.39. 3	+40.24.2	Nov. 24.00	1.33.33	+52.32.0
22.00	2.40.38	+41.21.4	27.26	1.30. 6	+51.41.0
24.54	2.41.57	+42.19.5	30.40	1.27.51	+50.44.9
27.12	2.42.59	+43.18.3	Dec. 3.39	1.26.45	+49.45.9
29.75	2.43.43	+44.17.9	6.23	1.26.37	+48.45.9
Oct. 2.42	2.44. 6	+45.17.8	8.90	1.27.19	+47.46.2
5.14	2.44. 0	+46.17.8	11.41	1.28.40	+46.47.7
7.90	2.43.31	+47.17.5	13.78	1.30.34	+45.51.0
10.71	2.42.27	+48.16.6	16.02	1.32.53	+44.56.2
13.56	2.40.51	+49.14.4	18.14	1.35.32	+44. 3.3
16.46	2.38.34	+50.10.0	20.16	1.38.28	+43.12.4
19.41	2.35.37	+51. 3.0	22.10	1.41.39	+42.23.0
22.40	2.31.56	+51.52.0	23.95	1.44.57	+41.35.6
25.44	2.27.33	+52.36.0	25.72	1.48.26	+40.50.1
28.54	2.22.26	+53.14.0	27.44	1.52. 1	+40. 5.7
31.70	2.16.39	+53.44.7	29.10	1.55.43	+39.22.9
Nov. 3.91	2.10.22	+54. 6.8	30.70	1.59.27	+38.41.6
7.18	2. 3.44	+54.19.2	Jan. 1.25	2. 3.15	+38. 1.6
10.51	1.56.54	+54.20.7	2.76	2. 7. 7	+37.22.7
13.88	1.50. 7	+54.10.4	4.24	2.11. 1	+36.44.5
17.27	1.43.46	+53.48.5	5.68	2.14.57	+36. 7.5
20.66	1.38.10	+53.15.1	7.09	2.18.55	+35.31.1

THE PLANET EROS.

W. W. PAYNE.

The planetoid Eros (433) is now occupying the attention of working astronomers more than any other one celestial object. On this account it will be of interest to many of our readers to have a re-statement of the principal facts about this new planet:

It was discovered by Witt of Berlin on August 13, 1898, when it appeared as a star of only the 11th magnitude. Its discovery, however, was not announced by telegraph until Sept. 5, which gave some information of its remarkable orbit which was then known to be in part, at least, within the orbit of planet Mars. An announcement of this discovery promptly appeared in the foreign scientific journals, especially in the *Astronomische Nachrichten*, No. 3512, in which attention was called to the rapid motion of the planet, which, on the average, was about 2000 seconds of arc daily.

During the same month and under date of Sept. 30, Professor E. C. Pickering of the Harvard College Observatory published a circular, which was numbered 34 in the regular series, setting forth much important information about the new, little planet. From the data then known relating to its path, it was found that its minimum distance from the Earth, where the orbit lies near the path of the Earth, was only 15,000,000 of miles. The importance of this interesting fact will at once appear, when it is remembered that the nearest approach of the planet Mars to the orbit of the earth is about 35,000,000 of miles, and that the Earth and Mars are so related in nearness of position, only once in 15 or 17 years. Since the planet Eros is distant from the Earth, at times of favorable opposition only 15,000,000 it is evident that this planet furnishes a most favorable means for the study of parallax, and astronomers are using the present opposition of the planet as an opportunity for prosecuting work of this kind most vigorously. For those who do not know how the parallax of the planets is determined approximately, it may be said that the parallax of Venus or Mars when nearest is only about 40 seconds of arc, a very small angle to measure accurately. The parallax of Eros is nearly 60 seconds of arc which, of course, is a more favorable angle for measurement on account of its increased size.

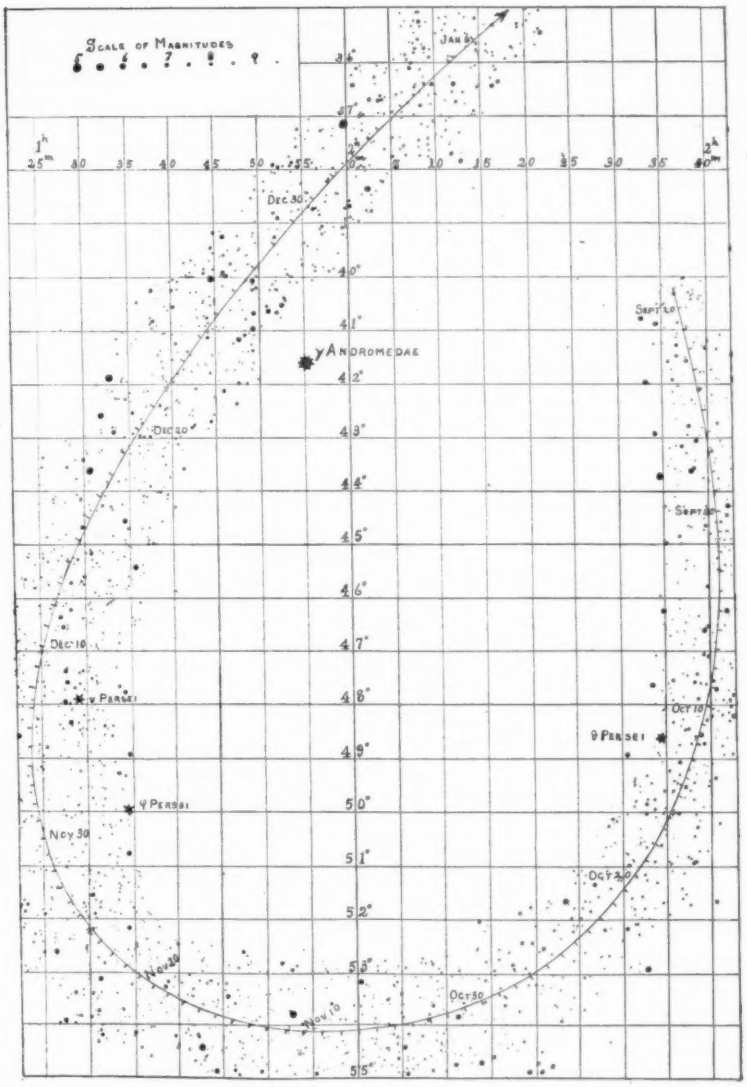
Astronomers know very accurately the ratio distances of all the planets in the solar system in units of the Sun's distance.

Now, if the parallax of any one planet can be obtained very accurately then the distance of all will be known, including that of the Sun in miles or other terrestrial units. This is the same old problem that has been before the minds of the students of the heavens since the dawn of the science of Astronomy.

The methods of the New Astronomy offer some advantages in the study of the problem. Photography is being used at a number of the larger observatories. But some difficulties are met in the work on this new planet which act as somewhat of a drawback, in the use of this favorite way of determining the places of the planet at specific times so as to map its path among the stars during the next few months to come. In the Harvard College Circular just referred to it was said that short exposures of Eros could not be used to determine the photographic brightness of the planet because it was so faint and its motion so rapid. Long exposure could not be used because the planet's trail could not be compared with the circular images of the stars near by to determine the planet's brightness relatively. The point of interest to observers now is can these planet trails on the photographic plates be used to determine the exact places of Eros in reference to adjacent stars, so that measures on the photographic plates may be employed to get the parallax of the planet. If so it will certainly give aid in the prosecution of this work in connection with the measures by the micrometer with visual objectives of a large aperture.

The photographic plan being tried at Goodsell Observatory with the 8¼-inch Clark refractor is to make exposures of plates for different lengths of time. The longer exposures to be broken for brief intervals at certain times which will be recorded on the chronograph. From such attempts already made, it seems clear that measures from the beginnings and ends of these trails, as points, may be taken to near stars that may be identified, on the plates, and in this way an accurate place of the planet may be known at the particular time of the observation. How well this plan will work out photographically we are not yet able to say, but we hope for results in a few days, if the nights are favorable.

The work of determining the places of Eros on every clear night by the aid of the micrometer and the 16 inch equatorial is carried forward with much interest and ease. It is not at all difficult to "pick up" the planet in the large instrument because of its rapid motion. By looking at such a chart of the path of Eros as ac-

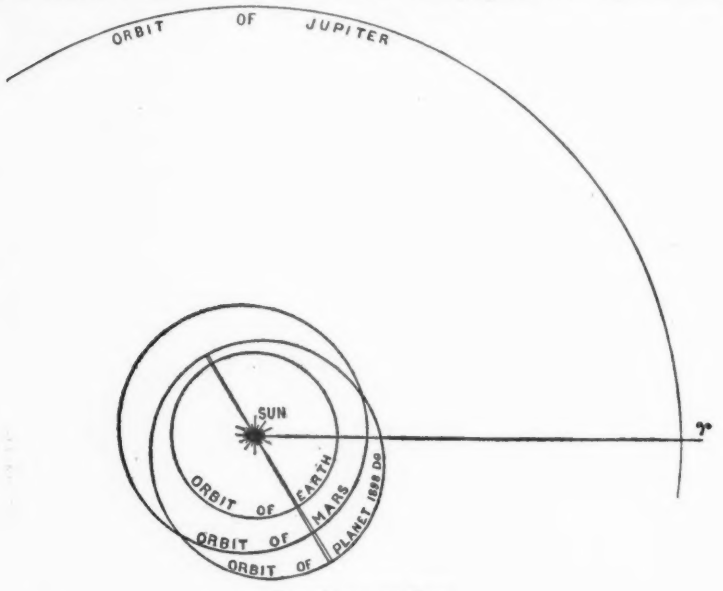


THE APPARENT PATH OF EROS AMONG THE STARS,
From Sept. 20, 1900, to Jan. 6, 1901.

The positions platted are for the epoch 1855. The precession to 1900 is approximately + 3m in R.A. and + 12′ to 14′ in Dec.

companies this article one can pretty certainly locate the moving star, which is easily and certainly determined in a few minutes by the aid of the micrometer wires and known adjacent stars.

For the aid of those who may not have seen a chart containing the orbits of the Earth, Mars, Eros and Jupiter we re-print one



THE ORBIT OF EROS.

herewith that was used in October 1898, when the planet was called DQ, and before it was named Eros.

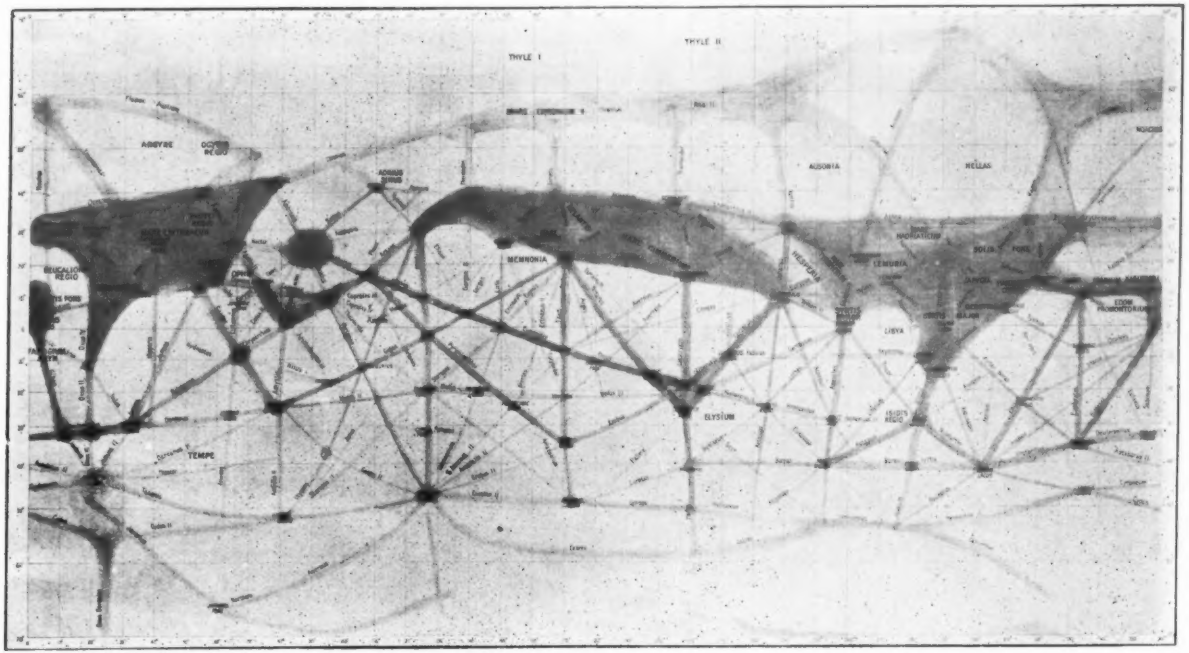
At another time more will be said of the details of both the photographic and the micrometric methods of determining the parallax of Eros.

RECENT WORK AT THE LOWELL OBSERVATORY.

W. W. PAYNE.

We have received Volume II of the Annals of the Lowell Observatory, the observations of which were made at Flagstaff, Arizona, and Tacubaya, Mexico, on Jupiter and his satellites in 1894 and 1895 and on Mars in 1896 and 1897. In July 1896, Mr. Lowell, the director of the Observatory received from Alvan Clark and Sons the new 24-inch telescope with which the astro-

PLATE XVIII.



MAP OF MARS, 1896–7.

nomical work of the Observatory was continued as mentioned above. In the completion of this telescope, utting it in place in the Observatory, and in adjusting it, Mr. Alvan G. Clark was much interested, as those who were present at the time very well know, and they speak of it really as his last work in the line of telescope-making. Those who have used this noble instrument are unsparing in praise of its fine—even its superb qualities.

In November of this year the entire Observatory was removed to Tacubaya, a suburb of the city of Mexico, where it remained until the end of March 1897, at which time it was removed again to Flagstaff where it has since remained.

In the Annals so far published, Volume I gives the complete work on Mars in the years 1894 and 1895. The volume before us "completes the strictly astronomical work of that year by giving that done on Jupiter and its satellites." The volume also commences the publication of subsequent work with the 24-inch instrument by presenting that on Mars in the second observational year, and the third year of the Observatory. This volume is therefore occupied with work relating to two objects: Mars and Jupiter and its satellites.

The observations on Jupiter in 1894 were made by William H. Pickering and those in 1895 by A. E. Douglass. Together they make the first long series of physical observations of the planet Jupiter and its satellites known to us. In this statement we do not forget the long, skillful and painstaking work of Professor G. W. Hough, of Dearborn Observatory, now of Evanston, Ill., who for more than twenty years, has been giving more or less attention to the surface markings of Jupiter, and who is estemeed a high authority, by astronomers generally, in relation to the physical characteristics of the planets.

The larger part of the work on the Jovian system in this was done by William H. Pickering, whose methods of research in 1895, were especially well adapted to gain the information desired. Later it fell to Mr. A. E. Douglass to carry through the mathematical part of this work by his own methods, yet with the consent of Professor Pickering. One peculiarity is noticeable in these observations and that is, that they are given complete in the original form in which they were made. The reasons assigned are two: one, because they are the first extensive, systematic study of the kind ever made, and second, because in most of the work the observer and the reducer were two different persons, and the equations of each enter into the results.

The observations of Mars were made by Mr. Lowell, the

Director, assisted by Mr. D. A. Drew, Miss W. L. Leonard and Mr. A. E. Douglass. Dr. T. J. J. See and Mr. W. A. Cogshall were also members of the Observatory, and made occasional observations. Mr. Douglass did, or had charge of, the reductions and the analytic study, save the tables of diameters by Mr. Lowell and such short preliminary articles as have been previously published by other persons belonging to the Observatory.

This quarto volume consists of 523 pages and, in general appearance is like the Harvard College Observatory Annals.

One distinguishing feature in addition to those already mentioned is the number and character of the plates and drawings. The first is a full page plate showing nine figures of Mars in color, representing the planet as seen between Jan. 9, and March 27, 1897. The drawings were made by Mr. Lowell and the reproductions are facsimiles that give a very close representation of the telescopic view in a large instrument, as we remember the appearance of the planet at that opposition. The heliotype printing of the plate is well done.

The observations and drawings of the Satellites of Jupiter by William H. Pickering together make a noble piece of astronomical work, for completeness and thoroughness in detail. On looking over this part of the volume we are reminded of the criticisms that were made upon some parts of it while it was in progress and the preliminary results only had been given to the scientific Journals. From the full representations given and the detailed observations that accompany them, it does not seem possible that Professor Pickering could have been mistaken in what he saw, or, even wrong in the general interpretations and conclusions which he drew from those observations.

If the observations had been irregular, less systematic and less extended, as must be said of other observers fairly when put in comparison with this series, then some of the objections offered might have more probability.

The lithographic work representing the markings of the four satellites of Jupiter is presented in many full-page plates, on which are given from a few to fifty drawings of each satellite by itself with the hour in Greenwich time and the position of the central meridian. The ellipticity of these satellites as well as their surface markings are objects of very great interest. It is especially surprising that the ellipticity of the different satellites should vary so much, and we do not see how the figures of the satellites

could be differently drawn from the numerical results of observation which are given so fully in detail.

The planet Jupiter is not figured, but the measures of the equatorial and polar diameters are given and the mean of these is $\frac{1}{16.11}$ somewhat greater than the value that has been generally accepted, that being about $\frac{1}{17}$.

The results of work on the satellites of Jupiter may be briefly stated as follows:

Satellite I appears to be a prolate spheroid revolving, end over end, about one of its minor diameters in a period of $13^h\ 00^m\ 38^s$ according to observations in 1894. In 1895 the period was within one minute of time of the same quantity. The axis of rotation is very nearly perpendicular to the plane of the orbit of the satellite, and the greater diameter seems to be inclined about 4° to the plane of the orbit, or 86° to the axis of rotation. The statement made by the author concerning these details is that they were seen without difficulty, and consisted of north and south lines, or belts, frequently bent at the center, and an occasionally bright equatorial belt.

Satellite II is the most difficult of the four, and very little in detail was learned about it by observation. An elliptical form is suspected and a north and south belt is thought to exist extending in a direction parallel to the supposed elongation.

Satellite III apparently has but slight ellipticity in a direction perpendicular to its orbit. Fifteen drawings of this satellite were made and the more conspicuous markings were a northern belt, rarely a central, forked belt, and once a southern belt. The white cap at the north pole of the satellite in 1894 and 1895 was a conspicuous object, and carefully observed at Mt. Hamilton as well as at the Lowell Observatory. In the 24 inch instrument this white north polar cap appeared to be associated with the northern belt, and the author of this description suggests that it is probable that one may be a contrast effect of the other. The time of rotation of this satellite is given as $2^d\ 9^h$ as determined by observations of this northern belt.

Satellite IV has a period of rotation of about five days, a time probably identical with its period of revolution about its primary. The markings on this satellite are an equatorial belt, sometimes forked, and on one date a well-marked southern belt, with a bright south polar cap. The drawings of 1894 and 1895 are in good agreement. The form of the fourth satellite is thought to be like that of the third, a prolate spheroid, keeping the same

face, constantly toward its primary, and turning on an axis inclined only 15° to its greatest diameter.

These satellites have different colors. "If the first is taken as a standard yellow, the second satellite has a trifle of red with it, the third a little green, and the fourth has red and green with only a little of the yellow."

The work on the planet Mars was done in the years 1896 and 1897 with the 24-inch Clark refractor. The range of positive eye-pieces used was of powers 186 to 1580. The least and the greatest negative eye-pieces were of powers 129 and 4138. The subjects of study were the polar caps of the planet, the diameters of the planet and the positions of the markings on the surface, the drawings and notes, the map of the surface for 1896-7, the double canals and the canals in the dark regions, the seasonal changes, limb and terminator observations and a summary of notes upon the meteorology and surface condition of Mars. Over one-half of this large volume is devoted to this planet. The deductions made from this large amount of observational matter may be briefly presented under a few heads as follows:

1. Concerning the existence of an atmosphere on the planet, the Flagstaff observers say: "Evidence is given of the existence of simple meteorological phenomena, occurring on Mars, the migration of the heat equator, the winds toward it and from it causing an interchange between the poles and the equator, cyclonic storms and diurnal effects. This, so far as it goes, sustains the idea that the meteorology of Mars is similar to our own, save in the changes caused by the limited water supply." As the polar caps sometimes disappear the heat equator must sometimes practically reach to the pole. This has never happened on the Earth in historic time, although geology and astronomy point to such possibilities at some remote time in the past.

2. In regard to moisture it is said that the quantity is very small, and appears chiefly at the heat equator, at certain seasons and near the polar regions. The increase in the polar indicates an increase of moisture in the late Martian autumn and winter, rising to maximum in the late winter, lessening in the spring and disappearing in the summer. It is an interesting sight to see one polar cap decreasing and vanishing when the cap at the opposite pole is forming and increasing. "This indicates an interchange of moisture between the summer and winter hemispheres. Radiation and polar clouds are the more common forms on Mars; cyclonic

and convectional clouds are very rare." It seems as if the larger transportation of moisture is aerial, while that on the surface of the planet is more limited.

3. The question of temperature has always been one of the most interesting ones in the study of the physical conditions of the planet. A knowlege of the temperature ought to aid in the explanation of the dark areas which are variable and therefore difficult to measure. It is noticed that the color of the dark markings in high latitudes changes from green, at the melting of the polar caps, successively to brown and yellow as the cap disappears. These changes are so much like those of the Earth, in regions near the equator, that there is reason to suppose that the dark markings on the planet mean vegetation. From all that can be gathered, it would seem that the mean temperature of the poles of the planet is likely not far below freezing point, and that the contrast between night and day is considerable.

The beautiful plate which is numbered XLI in the volume is reproduced to bring to the eye of the reader, a view of all the dark markings on entire surface of the planet to 70° of latitude north and south of the equator, as an aid to the description that precedes.

We ought to say in this connection that we have just received an interesting publication from V. Cerulli of the private Observatory at Collurania, which gives quite fully the observations of Mars for the years 1898 and 1899, and which contains all of the surface markings of the planet as seen two years later, which are presented also in a chart on about one-half the scale of the one prepared at Flagstaff. It will be profitable later to make a careful comparison of these two volumes giving study to the planet Mars, to so late a date.

SPECTROSCOPIC NOTES.

Spectroscopic science has suffered a severe loss in the sudden death Aug. 12 at San Francisco of Prof. James Edward Keeler, Director of the Lick Observatory.

Prof. Keeler's early experience in spectroscopic work was as a graduate student at Johns Hopkins University and as assistant in the spectroscopic and bolometric work of the Allegheny Observatory.

Leaving Allegheny for the Lick Observatory in the early history of that institution he there made his classical research on the motion of nebulæ in the line of sight, (*Publications of the Lick Observatory, Vol. III*). In this work he used a grating spectroscope attached to the 36-inch equatorial, using chiefly the third and fourth order spectra in order to secure the necessary dispersion. The uncertainty with regard to the absolute position in the spectrum of the chief nebula

line he sought at first to remove by assuming that the average velocity of the nebulæ measured was zero; an assumption admittedly dangerous on account of their small number and their unsymetrical distribution in the sky. Later the motions of the nebula of Orion and of the nebula G. C. 4390 were measured by a fine series of comparisons of the position of the *F* line of hydrogen as shown by these nebulæ with the position of the same line given by terrestrial hydrogen; the position of the chief nebula line as determined by comparison with a neighboring lead line was in each corrected for nebular motion and so was fixed definitively λ 5007.05 ± 0.03. The motions of the nebulæ were shown to be of the same order as those of the stars, ranging from 40.2 miles per second of approach to 30.1 miles per second of recession; with an average motion of perhaps 15 miles per second. The measures further showed indubitably a motion of the solar system in the direction previously indicated by proper motions of the stars.

Leaving the Lick Observatory after the completion of his work on the motion of the nebulæ Prof. Keeler was appointed Director of the Allegheny Observatory. Here his spectroscopic work was photographic. The plates used were usually isochromatic, which admitted of valuable work on the yellow and orange of the star spectra. Prof. Keeler's most conspicuous contribution to spectroscopic science during his residence at Allegheny was his spectroscopic confirmation of the meteoric constitution of Saturn's rings. In photograping the spectrum of Saturn for this purpose the isochromatic plates were sufficiently sensitive to allow the use of the yellow of the spectrum, while the granulation of the plates was sufficiently fine to permit the detection of inclination of excessively short spectral lines obtained from the small image of the planet given by the Allegheny telescope. The slit of the spectroscope was placed along Saturn's equatorial diameter, cutting the ball of the planet, and, beyond the vacant interval at each side, the rings. The lines in the spectrum due to the ball of the planet were inclined so as to indicate a rotation of the planet, though not to determine this rotation so accurately as it had been otherwise derived. The lines due to the rings were also inclined, but in the opposite direction, demonstrating that the inner edge of the ring moves faster than the outer; which is clearly impossible if the rings are solid.

The character and promise of Prof. Keeler's work was such as very properly to inspire a desire on the part of the citizens of Pittsburg and Allegheny that a large telescope should be available for its prosecution. Accordingly a movement was inaugurated for the erection of a 30-inch telescope and the removal of the Observatory to a new and more suitable site. Measures were being energetically taken to this end when the project was interrupted by circumstance arising from the outbreak of the Spanish war.

On the delay then ensuing Prof. Keeler accepted the offer of the position of Director of the Lick Observatory, which he held at the time of his death. Here, with what seems certainly rare generosity, he resigned not only the spectroscopic work of the Observatory, but the use of the great refractor as well, into other hands, and, discontinuing his spectroscopic work, has been engaged in securing his remarkable series of photographs with the Crossley refractor.

In the *Astrophysical Journal* for July, Exner and Haschek give measures of silicon lines, completely confirming Mr. Lunt in attributing certain lines in the spectra of several stars to silicon.

In the *Philosophical Magazine* for September Prof. Trowbridge describes his experiments on the spectra of hydrogen. The four line spectrum he found very readily produced in the presence of water vapor. The presence of the four line spectrum of hydrogen in the sun he regards as substantial evidence in favor of the presence in the sun of water vapor, and consequently of oxygen.

The *Astrophysical Journal* for July devotes fifty pages to American eclipse reports from the various parties along the path of totality. Spectroscopic work constitutes a considerable part of the total work of the larger parties.

The Naval Observatory was represented by three parties, two near the central line, at Pinehurst, N. C., and at Barnesville, Ga., and one just inside the northern limit of totality, at Griffin, Ga. The equipment included a prismatic camera, a slitless spectrograph, two grating objectives, and three concave gratings. The observations with the concave gratings for various reasons all failed. Dr. Huff with a grating objective (plane grating with quartz lens) at Pinehurst obtained three successful plates, one giving four corona lines in the ultra-violet. With the prismatic camera, using erythro plates, a good photograph of the spectrum of the flash was obtained, showinga large number of bright lines, including six or eight in the red and orange between C and D_3. Prof. Lord's observations with objective prism train seem to indicate a very short duration of flash. Mr. Jewell at the station near the limit of totality was able to observe the gradual appearance of the reversal of the metallic lines; and infers that the chromosphere is dense at its base, probably merging into the upper photosphere.

With the Smithsonian party at Wadesboro, N. C., the objective prisim with the 135 ft. lens, which was responsible for the striking bifurcated appearance of that apparatus, for some unknown reason failed to give any results.

In the Princeton party at Wadesboro, N. C., Prof. Miller observed in the flash fewer lines than had been expected, and at mid totality saw eight bright rings. Prof. Young, contrary to his experience at three previous eclipses, was entirely unable to see the green corona line, and Mr. Russell was equally unsuccessful. The plate exposed in the large spectrograph especially with a view of determining the position of the corona line in the spectrum failed to show any trace of the line.

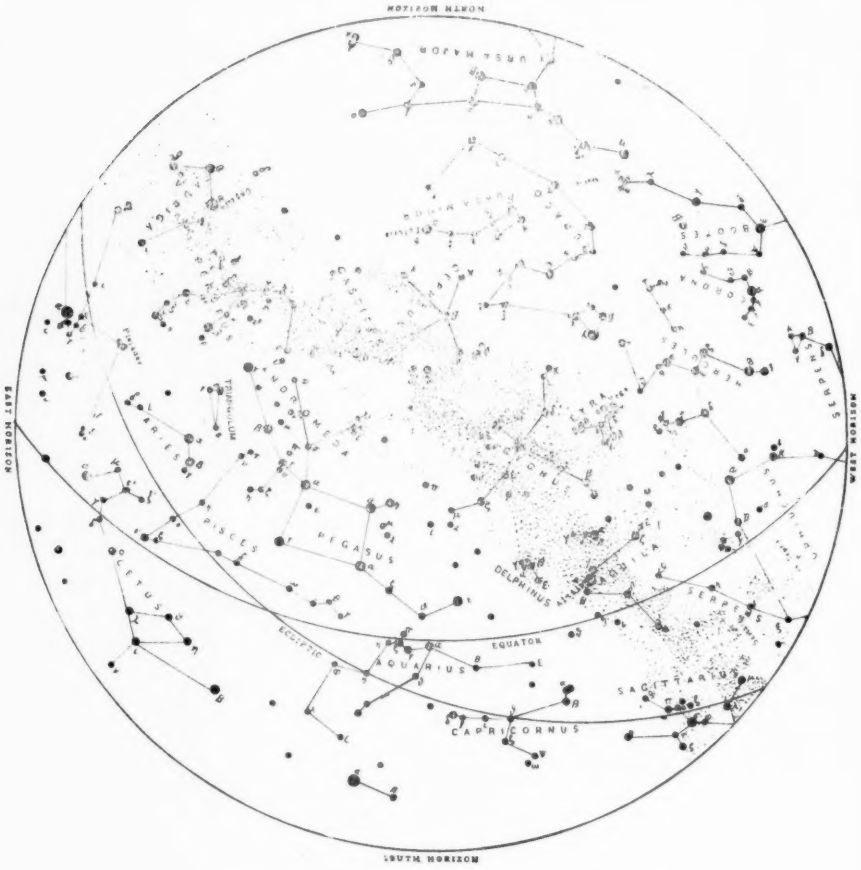
In the Yerkes Observatory, also at Wadesboro, Prof. Frost, assisted by Dr. Isham, obtained photographs of the flash spectrum at second and third contacts and of the spectrum of the cusps some seconds after totality. One plate of the violet part of the corona spectrum was secured, showing several chromosphere lines and one or possibly two corona lines. No results were secured from the attempt to obtain a photograph of the red end of the spectrum with a plane grating.

In the party from Brown University, stationed at Centerville, Va., Mr. Slocum used successfully a prismatic camera, securing plates which show a considerable number of bright lines, including prominently the chief chromosphere lines.

PLANET NOTES FOR OCTOBER.

H. C. WILSON.

Mercury will be evening star during this month, coming to greatest eastern elongation, 23°44′ from the Sun, on Oct. 29. The planet may then be seen near southwestern horizon soon after sunset, but only for a short time.



THE CONSTELLATIONS AT 9 P. M., OCTOBER 1, 1900.

Venus is the bright star in the east, rising a little before three o'clock and reaching the meridian about nine o'clock in the morning. Her course is south-

eastward through Leo. On the morning of Oct. 7 Venus will be in conjunction with the first magnitude star Regulus, the former being about one degree north of the latter. The waning moon will be in conjunction with Venus on the 19th.

Mars rises toward the northeast about midnight, and moves eastward through Cancer during this month. The planet is conspicuous for its ruddy color to the naked eye, being a little redder and brighter than the star Aldebaran. The Moon will be in conjunction with Mars on the night of October 16. The distance of Mars from the Earth is about 158,000,000 miles and the apparent diameter of the disk of the planet is only six seconds, so that observations of its surface-markings are yet very difficult.

Jupiter, *Saturn* and *Uranus* are evening stars but too low in the southwest for observation except during the twilight.

Neptune rises between nine and ten o'clock in the evening and may be observed under favorable conditions during the latter half of the night. The position of the planet October 1 is R.A. $5^h\ 56^m\ 38^s$, Dec. 22° 13′ 16″, North.

Eros—The *Astronomische Nachrichten* No. 3662 contains an extension of the ephemeris of Eros, by Millosevich, from Jan. 1 to April 1, 1901.

The Moon.

		Phases.	Rises. (Central Standard Time at Northfield; Local Time 13m less.) h m	Sets. h m
Oct.	1	First Quarter.....	1 32 P. M.	10 59 P. M.
	8	Full Moon.....	5 31 "	7 48 A. M.
	15	Third Quarter.....11	45 "	2 10 P. M.
	23	New Moon.....	6 50 A. M.	5 06 "
	31	First Quarter.....	1 32 P. M.	12 15 A. M.

Occultations Visible at Washington.

Date. 1900.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	Angle f'm N pt. °	EMERSION. Washington M. T. h m	Angle f'm N pt. °	Duration. h m
Oct.	1	29 Sagittarii	5.5	8 32	17	9 15	308	0 43
	5	Lalande 44337	6.3	12 44	121	13 17	184	0 33
	6	9 Piscium	6 6	6 56	7	7 33	299	0 37
	6	16 Piscium	5.8	12 01	79	13 08	223	1 07
	6	19 Piscium	4.9	17 17	27	17 52	295	0 35
	10	13 Tauri	5.7	15 16	142	15 54	200	0 38
	12	ζ Tauri	3.3	11 27	75	12 33	275	1 06
	15	29 Cancri	6.0	16 07	76	17 18	324	1 11
	26	Uranus	.....	5 26	95	6 39	256	1 13
	27	52 Ophiuchi	6.5	5 32	50	6 39	290	1 07
	27	B.A.C. 5954	6.8	7 28	56	8 27	283	0 59
	29	B.A.C. 6658	7.3	7 56	11	8 33	307	0 37

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

(Given to the nearest hour in Greenwich Time.)

1900.

U CEPHEI.

	d	h
Nov.	2	12
	5	0
	7	12
	10	0
	12	11
	14	23
	17	11
	19	23
	22	11
	24	22
	27	10
	29	22

ALGOL.

	d	h
Nov.	1	9
	10	0
	12	20
	15	17
	18	14
	21	11
	24	8

U CORONAE.

	d	h
Nov.	1	13
	5	0
	15	8
	22	6
	25	17

W. DELPHINI.

	d	h
Nov.	4	12
	9	8
	14	3
	18	23
	23	18
	28	13

λ TAURI.

	d	h
Nov.	4	8
	8	7
	12	6

S CANCRI.

	d	h
Nov.	7	20
	17	8
	26	19

R CANIS MAJ.

$P = 1^d\ 3.3^h$.

Oct.	31	0
Nov.	30	16

Y CYGNI.

$2P = 2^d\ 23.9^h$.

Odd min.

Oct.	28	15
Nov.	27	15

BD + 45°3062.

	d	h
Nov.	2	15
	7	5
	11	19
	16	9
	20	22
	25	12
	30	2

Maxima and Minima of Long Period Variables.

1900 December.

MAXIMA.

	Day.
SS Cygni	2?
T Eridani	4
RU Cygni	5
V Aquarii	6
T Centauri	6
RV Herculis	7
T Leporis	7
X Cassiopeae	8
U Arietis	9
RT Herculis	9
X Librae	9
T Camelopardalis	10
R Aquarii	11
Y Librae	11
V Cephei	12
W Persei	13
T Andromedae	15
Z Librae	15

MAXIMA, Con't.

	Day.
W Capricorni	16
X Delphini	17
R Virginis	17
W Librae	18
Z Ophiuchi	20
X Ceti	23
Z Cygni	23
RX Sagittarii	24
T Delphini	25
V Leonis	27
RR Sagittarii	28
R Trianguli	29
U Bootis	30
T Geminorum	30
R Cancri	31
Z Sagittarii	31
R Vulpeculae	31
R Ceti	32

MAXIMA Con't.

	Day.
S Delphini	32
RR Cygni	32
R Orionis	32

MINIMA.

R Columbae	1
U Orionis	3
Y Virginis	5
X Geminorum	8
R Camelopardalis	19
R Cassiopeae	20
U Canis minoris	21
R Ursae Majoris	23
S Ursae "	26
R Sculptoris	29
R Bootis	31

NOTES TO THE EPHEMERIS.

The dates are taken as before from Dr. Hartwig's paper in the *Vierteljahrsschrift*, except for Y Cygni for which I have used Duner's data given in No. 3633

of the *Nachrichten*. These times are two and three hours later than those in Hartwig's ephemeris.

W Persei is called V Persei in Chandler's Third Catalogue.

SS CYGNI.—The maxima are now about a month behind the ephemeris, which is founded on the changes observed previous to the reversal of the order of maxima which occurred in the early part of 1900. The rise which was set for Aug. 8 by this ephemeris, did not take place till Sept. 7.

OBSERVATIONS OF VARIABLE STARS AT THE GERMAN OBSERVATORIES.

The following items of news are extracted from Part 2 of Vol. 35 of the *Vierteljahrsschrift*, which has just appeared.

BAMBERG.—For the year ending May 1, 1900, Dr. Hartwig reports 733 observations of variables by Argelander's method. Of this number 77 referred to SS Cygni. Of this star the intervals between the times of rise since Oct. 25, 1899, were 32, 35, 69 and 48 days. U Geminorum was found bright from April 1 to 3. Minima of Algol and λ Tauri were observed on three nights, and light estimates were made of β Lyrae, η Aquilae and δ Cephei on 18 nights. The variability of one of the Pleiades stars, B.D. + 24°531, was discovered by photography. Its magnitude in the B.D. is 9.5, but it was fainter than 12th magnitude in November 1899 and certainly fainter than 11th magnitude in April 1900.

HEIDELBERG.—Dr. Valentiner announces the early publication of Schönfield's original observations of variable stars. Most of them were made at Mannheim from 1865 to 1875. There are 35963 complete observatons of 117 variables, comprising over 80000 single estimates, besides 4000 or 5000 comparisons of the comparison stars among themselves. It is needless to say that the quality of these observations is fully equal to the quantity, and the publication will be simply invaluable.

MUNICH.—Observations of Nova Aurigae were continued and a decline of 0.2 magnitude was recorded in 1899. On the 22d of December it was estimated as 12.7 or 12.8 magnitude.

VIENNA.—(*The Von Kuffner Observatory.*) Dr. Wirtz has continued the investigation begun by Dr. Schwartzchild of the determination of the photographic light curves of variables. Preliminary reductions lead to the conclusion that the curve for δ Cephei resembles that for η Aquilae, that is the photographic amplitude is nearly double the optical, thus showing a decided increase of redness at minimum.

OBSERVATIONS OF FAINT VARIABLES AT THE YERKES OBSERVATORY.

The greater part of the work hitherto done on variable stars consists in determinations of their maxima and periods, comparatively few of them being followed through the complete cycle of their change. As a result our knowledge of the variation of most stars is fragmentary. For this reason the opportunity to observe faint minima with the Yerkes 12 and 40-inch telescopes was welcomed by the writer, and the following items from the work done between January and August, 1900, may be of interest. They are extracted from Bulletin No. 13 of the Yerkes Observatory:

This preliminary report will be followed by more definite results when the magnitudes of the comparison stars have been determined with the stellar photo-

meter, now in use in this work. The magnitudes given in the present paper are only approximate, based on the assumption that the limit of the 12-inch is 14.0 magnitude, and that of the 40-inch 17.0 magnitude.

Of the 22 stars in this report, 16 are contained in Chandler's *Third Catalogue of Variable Stars* and supplements. For these stars Table I gives from this catalogue the minimum magnitude and number of minima on record, to show what was previously known on the subject; also the results of the work at the Yerkes Observatory from January to June 1900, giving the date and magnitude of the observed minima.

TABLE I.

	From III. Cat.		Yerkes observations	
	Min. mag.	No.	1900	Min. mag.
267 V Andromedae	——	—	January	14
2530 V Canis minoris	<13.7	—	April	15
2625 V Geminorum	12.0–14.0	3		
2815 U Geminorum	13.1	—		
2976 V Cancri	<12	3	February	12
4315 R Comae	<13.5	—	March	<14
5070 Z Virginis	<14	—	May	15
5430 T Librae	<14.7	3	Feb. or Mar.	<16
5593 W Librae	<14	—		
5830 R Scorpii	<13	—	May	16
5831 S Scorpii	<13	—		
6100 RV Herculis	——	—	February	<15
6871 V Lyrae	<12	—		
6894 S Lyrae	12.0	—	May	16
7458 V Delphini	12?	—		

Six of the stars in Table I did not pass minimum during the time covered by this report; the following notes show the observed magnitudes, the stars being referred to by their numbers only:

2625 14.5 magnitude by the end of January, brighter by middle of February.

2815 Carefully followed throughout its period. About 14 magnitude at normal light, but with considerable fluctuations.

2976 Has a 13 magnitude companion, 10″.8 preceding, on the parallel.

5593 15 magnitude and rising early in February.

5831 Apparently stationary at 15 magnitude in February.

6871 About 15.5 magnitude early in June and still fading.

7458 Maximum 1899 October 1, at 7.5 magnitude; invisible in 40-inch (low power) 1900 July 20, therefore <17 magnitude: a range of nearly or quite 10 magnitudes.

Particular attention has been paid to new variables, not in the Third Catalogue, whose light-curves suggest very faint minima. Table II gives six stars selected from these, showing the number (in parenthesis, provisionally assigned by the writer), the place for 1900, found by micrometer measures with the 40-inch, except for the 2d and 5th, the discoverer, and a reference to the announcement of discovery in the *Astronomische Nachrichten*.

TABLE II.

STARS NOT IN CHANDLER'S THIRD CATALOGUE.

	1900. R. A.			1900. Dec.			Discoverer	*Ast. Nach.* Vol.	*Ast. Nach.* Page.
	h	m	s	°	′	″			
(1922)	5	20	8.6	+36	48	53	Ceraski	148	15
(4696)	13	2	39.5	−12	37	50	Schwassmann	152	183
(6458)	17	56	17.2	+54	52	45	Anderson	151	307
(7258)	20	11	32 9	+30	46	3	Anderson	150	325
(7579)	21	3	38 5	+82	39	50	Ceraski	147	142
(8517)	23	39	41.1	+56	1	35	Anderson	148	79

The preliminery results of the observations of these new variables are given in the followlng notes:

(1922) Minimum early in March, about 15 magnitude.

(4696) Not visible in the 12-inch June 20, limit about 13 magnitude. Between 13 and 14 magnitude July 5, with 40 inch.

(6458) Not visible in 12 inch in March, limit 14 magnitude, had risen to 10 magnitude by June 23.

(7258) Minimum in May, about 14.5 magnitude.

(7579) Had passed below the limit of the 40-inch in June, and therefore not brighter than 17 magnitude.

(8517) Stationary at about 15 magnitude in January, rising in February.

COMET NOTES.

EPHEMERIS OF COMET *b* 1900.

1900.		α app. h	m	s	δ app. °	′	Log *r*	Log Δ	B.
Oct.	1	14	29	45	+68	38.1	0.1492	0.1105	0.07
	3		32	53	68	11.0	1559	1193	06
	5		35	55	67	46.6	1625	1277	06
	7		38	55	67	24.5	1691	1357	06
	9		41	53	67	4.8	1757	1434	05
	11		44	50	66	47.3	1822	1508	05
	13		47	44	66	32.0	1887	1579	05
	15		50	38	66	18.7	1951	1646	04
	17		53	33	66	7.6	2015	1711	04
	19		56	27	65	58.3	2078	1773	04
	21	14	59	22	65	50.9	2141	1833	04
	23	15	2	16	65	45.6	2202	1890	03
	25		5	12	65	42.1	2264	1946	03
	27		8	8	65	40.4	2324	1998	03
	29		11	4	65	40.5	2384	2049	03
	31	15	14	2	+65	42.4	0.2444	0.2098	0.03

Search Ephemeris for Comet 1884 II, (Barnard).—This comet was not found at its return to perihelion in 1894 and 1895 because of its unfavorable situation. This year again its position is quite unfavorable. It will be at perihelion, according to the ephemerides on October 28, 1900, and will then be only from three to four hours east of the Sun, and about thirteen degrees farther to the south than that body. In the southern hemisphere the situation is somewhat

more favorable and it may be possible that the comet may be found. In the *Astronomische Nachrichten* No. 3660, Dr. Berberich gives a search ephemeris of the comet, a portion of which we give here.

Date Berlin Midnight.		R. A. h m	Dec. ° ′	Log r	Log Δ	Light
Oct.	3	16 13.8	−25 45			
	7	16 28.5	26 13	0.1170	0.2001	0.23
	11	16 43.6	26 37			
	15	16 59.0	26 55	0.1123	0.2016	0.24
	19	17 14.8	27 07			
	23	17 30.9	27 12	0.1097	0.2042	0.24
	27	17 47.2	27 11			
	31	18 3.7	27 04	0.1095	0.2080	0.23
Nov.	4	18 20.3	26 50			
	8	18 36.9	26 29	0.1114	0.2135	0.22
	12	18 53.4	26 01			
	16	19 09.9	25 26	0.1155	0.2207	0.21
	20	19 26.2	24 45			
	24	19 42.4	23 57	0.1216	0.2298	0.20
	28	19 58.3	23 03			
Dec.	2	20 13.9	−22 05	0.1295	0.2405	0.18

As the time of perihelion is uncertain by two or three weeks the observer will need to extend his search to a considerable distance on each side of the predicted place of the comet, possibly as far as a half hour in R. A. and a degree or more in Dec.

GENERAL NOTES.

We have greatly tried the patience of our subscribers for the last three issues, sometimes for good and sufficient reasons, and sometimes for reasons, though beyond our control at the time, were not good reasons. We believe that we will have no more trouble of this kind, and that hereafter each number will be mailed on time.

We have given considerable space in this number to useful tables for the observations of the planet Eros, because there are so many observers who are supplied with telescopes who may wish to do some work of this kind during the weeks to come, that such aid may be quite widely useful.

Observations of the Partial Eclipse of the Sun, May 28, 1900, at Orono, Maine.—

Longitude $4^h\ 34^m\ 40^s.5$ W.
Latitude $44°\ 54'\ 3''$ N.

Observer	A. R. Crathorne	F. C. Mitchell	L. H. Homer
Instrument	4-in. Clark telescope	Repsold Vertical Circle	3-in. telescope
First Contact	$8^h\ 1^m\ 1^s$	$8^h\ 0^m\ 33^s$	$8^h\ 0^m\ 27^s$
Last Contact	10 37 12	10 37 11	10 37 15

Times are reduced to Eastern Standard Time.

The Recent Solar Eclipse.—The report of the expeditions organized by the British Astronomical Association to observe the total solar eclipse of May 28, 1900, will be contained in a volume shortly to be issued from the office of *Knowledge*. The work will be edited by Mr. E. Walter Maunder, F. R. A. S., and will contain many fine photographs of the various stages of the eclipse.

Observation of Contacts by the Creighton University Party at Washington, Ga.—The internal contacts were observed with the naked eye. The external contacts were observed by projecting the Sun's image upon a white screen secured by two light wooden rods beyond the eye-piece of a 3-inch telescope. I prefer this way of observing the Sun to the more usual direct-vision method by means of a sunshade or helioscope, because the projection method does away with the heat and glare of the Sun, admits of the use of both eyes and of any desirable magnifying power, is equal, if not superior, in accuracy of observation, and especially because it enables the observer to mark the point of first contact upon the screen and thus obtain the advantages of a position micrometer from a telescope of the most ordinary construction and mounting.

The comparison of observed and computed time is as foliows:

Central Time.	I	II	III	IV
	h m s	h m s	h m s	h m s
Computed	6 33 17.0	7 40 57.1	7 42 23.0	8 59 29.8
Observed	6 33 18.3	7 40 50.0	7 42 16.0	8 59 18.6
Computed — Observed	— 1.s3	+7.s1	+7.s0	+11.s2

	Mid Totality	Duration of Totality	Duration of Whole Eclipse
	h m s	m s	h m s
Computed	7 41 40.0	1 25.9	2 26 12.8
Observed	7 41 33.0	1 26 0	2 26 0.3
Computed — Observed	+7.s0	—0.s1	+12.s5

The correction and rate of the chronometer were obtained from the Naval Observatory noon signals at the railroad depot.

The geographical coördinates of my position were, latitude 33° 44′ 13″ N., longitude $5^h\ 30^m\ 58^s.9$ W.

WM. F. RIGGE, S. J.

CREIGHTON UNIVERSITY OBSERVATORY.

Comet *b*, 1900.—The independent discovery of this comet by Borrelly and myself was made on the same morning, July 23, and at nearly the same date of local time, the instant of my discovery preceding Borrelly's by a few minutes. Although the difference in longitude between the two stations favors my esteemed fellow-worker by about five hours, it is an interesting fact, that the Harvard cablegram announcing my discovery of the comet, reached Kiel two hours before Borrelly's announcement was received. The comet has been an exceedingly fine telescopic object in the 10-inch refractor. For some time after discovery it bordered closely on naked eye visibility. The nucleus and coma were easily visible with the telescope in the presence of a full Moon. Although it is now rapidly fading, the comet will from its favorable position in the northern heavens, remain visible in large apertures for some time to come. Soon after discovery two faint branches or auxillary tails were detected, one upon each side of the main tail. Although the principal tail has become much fainter, as the comet receded from the Sun, it has very singularly maintained its original length of about one degree.

In the first note on page 396 of September number Dr. Wilson inadvertently places my Observatory at Rochester. It is where it has been for thirteen years past, at Geneva, N. Y. On the other hand, the name of their Observatory is Smith Observatory, and not the peculiar name given to it by the compositor at the foot of my note on page 400.

WILLIAM R. BROOKS.

SMITH OBSERVATORY, Geneva, N. Y.
Sept. 10, 1900.

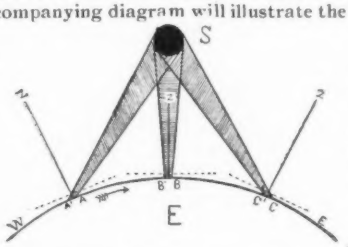
New Form of Telescope.—Referring to telescope decribed in *Popular Astronomy*. No. 77 page 379, allow me to say that the principle of such a telescope is by no means new. About the year 1872-3 I sent to the English Mechanic drawings of a somewhat similar instrument with concave-convex lens, and in 1870-1 I made a 5-inch aperture telescope on that principle a plano-convex lens having its aberrations corrected by a smaller concave lens and mounted as a Newtonian Telescope for a gentleman then going to India, uncle to Stanley E. Lane Poole, Esq., now I believe of the British Museum Library, who informed me that it was a success, but I heard nothing from the owner and concluded that he did not consider it worth pursuing. In any instrument of considerable aperture there certainly must be trouble and not a little of it with the oblique rays: and this very important point seems to have been entirely overlooked by the ingenious projectors. Nor is this at all an unusual phenomenon. Any one reading over the accounts published by Dr. Smith, of Geneva, N. Y., some twenty years ago, of Mr. Ingalls, of Liverpool, England, Dr. Wilson, of Edinburg, and Professor Barlow of their various dialytic instruments and of Dr. Blair, of Edinburg of his third lens, would think from what they say of them there was nothing to be desired. All the said lenses are reported to be even when used under high power, perfectly free from aberrations, either chromatic or spherical, etc. and if so what became of them, for although they were, some of them, of eight or nine-inch aperture; we never hear of them again.

Mr. Wray, a celebrated English maker pursued the matter most perseveringly, he constructed one of nearly 20 inches aperture, but was obliged to confess, as indeed any one may see who will go to work and trace the rays through geometrically, that nothing could be done with the oblique rays, although he went to great trouble in making special eyepieces for it. So that he at length gave it up. Many others have tried with no better success. Then the difficulty of proper adjustment would be very great and of keeping the various surfaces, in proper ajustment, still greater, to say nothing of the trouble and expense of figuring and testing at least 5 surfaces. So that one may well ask where would the saving come in? It would be, not a simplified achromatic, but rather a highly complicated reflector and that is really all there is to it.

CAMDEN, N. J. E. M. TYDEMAN.
Sept. 8, 1900.

An Interesting Phase of the Recent Solar Eclipse.—One of the most noticeable features of the recent solar eclipse was the rapidity with which the light returned after totality. At one minute after totality the landscape was quite as bright as it was at 10 minutes before totality. It would naturally be supposed that the gradation from sunlight to darkness and from darkness to sunlight would be the same before and after totality. But this did not seem to be the case. The difference was so marked as to preclude any theory of "illusion" or of "effect of contrast," there was no doubt in the writers mind that it was a real appearance. Other observers, when questioned, testified to the same effect. Miss Bacon, of the British Astronomical Asso., observing in this country, noticed the same appearance, and made particular mention of it in her report, remarking that "there is at present no theory that will account for this phenomenon, which is not at all what might be expected. This point alone will afford food for speculation and research." The text-books do not mention the phenomenon, nor is there any explanation of it in the recent astronomical journals.

With a view of bringing this question up for solution or discussion the writer wishes to advance the following theory of the phenomenon and believes that it is due to the inclination of the Moon's shadow to the Earth's surface. The accompanying diagram will illustrate the theory.



In the diagram *S* is the eclipsed Sun, *A*, *B* and *C* the observer's position at forenoon, noon and afternoon respectively, the lines drawn from *S* to *A*, *B* and *C* are the Moon's shadow, the dotted lines indicate the horizontal view and *Z* the zenith at the various positions, the arrow indicates the direction of the Moon's shadow over the earth's surface.

When the observer is at *A*, where the totality occurs at about 9 o'clock in the morning, the Sun will be in the east about half way to the zenith and the Moon's shadow will stretch across the zenith to the west, thus covering about three-fourths of the observers sky, leaving only one-fourth of the sky in the sunlight. As the shadow approaches, the light will fade rapidly before totality. When the shadow has passed the observer's position, and he is in a position corresponding to *A'*, and the Sun begins to be uncovered, it will be seen that three-fourths of the sky will be in the sunlight, and only one-fourth in the shadow. This will cause the light to increase rapidly, which corresponds to the observations above stated.

When the observer is at B the Moon's shadow will be in the zenith and the illuminated sky will be the same at a given time before and after totality. Therefore the light should fade and return in about the same way before and after totality.

When the observer is at C, when the totality is at 3 o'clock in the afternoon, the effect should be opposite to that of the observer at A, and the light be greater before than after totality. The Sun will then be in the west about half way to the zenith; but the moon's shadow will cover only about one-fourth of the observer's sky, leaving three-fourths in the sunlight. This will cause the light to fade slowly before totality. After the shadow has passed, and the osberver is in a position corresponding to C', three-fourths of the sky will be covered by the shadow leaving only one fourth of the sky in the sunlight. This will cause the light to return slowly.

At all stations between A and B, the effect should be the same as at A, but in a less marked degree, and in the same way at all stations between B and C, the effect should be the same as at C, though in a less marked degree. The nearer the observer is to noon at totality the less will be the gradation of light and shadow before and after. The farther the observer is from noon at totality the greater will be the contrast before and after totality.

It may be remarked, in conclusion, that in the case of the recent eclipse no observations were made at the noon period—that occurring in the Atlantic Ocean but there were numerous observers in the afternoon, though not many in the late afternoon, where the contrast would be great enough to attract attention. It would be well for future observers of total eclipses to pay some attention to this feature, so that more light may be thrown upon this interesting question.

BROOKLYN, N. Y.
September 10, 1900. A. J. B.

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